Geothermal Heat Pumps: Energy Efficient Heating Solution for the East Coast Row House

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School of Architecture
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Doctorate Project Committee
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We certify that we have read this Doctorate Project and that, in our opinion, it is satisfactory in scope and quality in fulfillment as a Doctorate Project for the degree of Doctor of Architecture in the School of Architecture, University of Hawai'i at Mānoa.

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I dedicate this document and the fulfillment of my Doctorate to my beloved wife Thea, for without her unwavering strength and support none would be possible.

A special thank you to my family and friends who encouraged and motivated me throughout this journey. To all my mentors and research contributors, I am deeply grateful for your guidance and the wealth of knowledge you have bestowed upon me.

ABSTRACT

This research document examines the home heating and cooling costs of historic row houses on the eastern coast of the United States and the best option for preservation and adding value added to these homes. The goal of the research is to identify the most energy efficient solution for East Coast Row House (ECRH) homeowners who are unable to afford the high cost of oil and gas space heating and cooling systems that are typically found in historic homes in need of preservation renovations. Professional literature, field knowledge from empirical case studies, and government produced data highlight the necessity for a utility retrofit to reduce energy wastefulness, and the high financial burden on homeowners.

The historical context of ECRHs and the methodology for undergoing a retrofit lay the foundation for this research investigation. Comparative analysis on home heating systems, with focus on costs, efficiency, and returns, provides justifiable reasoning for the goal solution. This research concludes that the best feasible option for ECRH homeowners is to incorporate a Geothermal Heat Pump (GHP) system and improve the thermal envelope via insulation. The evidence in this research supports the proposal that a GHP retrofit can drastically reduce utility costs by 40 percent, increase market value, preserve historic qualities and longevity of the house, and provide investment return within ten years of installation.

ECRHs currently account for 34 percent of homes on the East Coast with the average home heating bill as much as $2,298 a year. Data shows that currently less than one percent of homes in the United States use GHP while it is confirmed that it reduces home heating costs between 40 and 70 percent. Lack of GHP knowledge and awareness of associated government benefits is an identifiable reason for low residential usage of GHP in the United States. This research targets the large population of homeowners who are unaware of efficient and viable options such as GHP, and are in need of this knowledge the most in order to better their lives.

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1 INTRODUCTION

1.1 Purpose

Space heating is one of the biggest concerns of home owners as it makes up 40 percent of utility costs, especially in cold climate regions.[1] This problem is exacerbated by the lack of efficient heating systems in place, particularly in historic row houses that make up 34 percent of residences on the East Coast.[2] Historic buildings have an added need for adequate cooling systems in addition to heating as the luxury of comfort cooling was not a priority during the building period of the 18th - 19th century. These structures currently face costly preservation limitations and challenges in order to update and maintain two separate space conditioning systems that were not included in the buildings original design. The solution to this problem is investment in a long-term and efficient dual heating and cooling system that is affordable to the homeowner and increases the value of the home to preserve it for the future. This research document highlights and outlines the existing expert knowledge pertaining to the heating and cooling efficiency dilemma in historic East Coast Row Houses (ECRH) and the possible solutions. The evidence collected and detailed in this research document indicates that the most viable sustainable and efficient space heating and cooling solution for a ECRH is a Geothermal Heat Pump (GHP) retrofit. I propose that when a GHP system is integrated into an ECRH, the utility costs can decrease by at least 40 percent, the investment gain will be realized within 10 years, the market value of the home will increase, and the historic qualities of the home will be preserved.

The target audience for this research are the historic preservationists, sustainable architects, policy makers, and homeowners in demand of innovative solutions for heating efficiency. The comparison of existing heating practices to the underutilized GHP will be extremely valuable and contribute to the existing body of knowledge through its summation and accessibility. The U.S. Department of Energy finds that less than one percent of homeowners utilize geothermal heating for their residences yet the

[1] "Geothermal Facts," Geoexchange Organization, accessed April 15, 2012, http://www.geoexchange.org/downloads/GB-019.pdf.
[2] "Census Housing Table Records," Census Bureau, accessed April 19, 2012, http://www.census.gov/hhes/www/housing/census/historic/units.html.

Environmental Protection Agency (EPA) confirms that home owners can save between 30 and 70 percent on their heating costs with this system (Geoexchange).[3] The reason geothermal heating makes up such a small percentage of usage is because of the general lack of knowledge and promotion in this country (*ibid*, 3). Conversely, the European Union is well versed in this system and has successfully incorporated it into its *Energy Efficient Building Initiative*.[4] This program and similar case studies are detailed in this research document, illuminating the validity of geothermal heating as a viable solution to reduce home heating costs.

1.2 Research Objectives

The unnecessary plight of homeowners to under heat or cool their residences because of utility costs from antiquated systems is the basis for this research. The *New York Times* published an article on January 21, 2012, detailing the heating dilemma for homeowners as a “crisis for the poor” who are “trapped in a cycle of spending more and more for heat.”[5] The article cites the "Low Income Home Energy Assistance Program" that provided homeowners with funds to offset the costs of oil and gas heating was cut for 2012 leaving many people on the east coast in dire straits. Concurrently, the demolition of historic ECRHs due to lack of preservation and thereby market value is exacerbated by families who cannot afford to maintain the homes in livable condition to make it worth saving. These homes are located in prime city center areas where the value of the land is more often economically valuable than the historic quality of the building if not maintained. According to the 2010 United States Census Records, the average townhome has been on the decline, particularly in those residences that are older with antiquated utility systems.[6]

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[3] "Geothermal Energy Impact," Department of Energy, accessed April 17, 2012, http://www1.eere.energy.gov/geothermal/pdfs/geothermal_risk_mitigation.pdf
[4] “Renewable Energy In Buildings,” Intelligent Energy Europe (IEE), Project Report 9, IEE-Library.eu, April 2009, accessed April 23, 2012.
[5]Diane Cardwell and Clifford Krauss, "Heating Oil Costs," *The New York Times*, January 21, 2012, accessed April 17, 2012, http://www.nytimes.com/interactive/2012/01/22/business/energy-environment/high-heating-oil-costs-hurt-more-in-northeast.html?ref=business.
[6]"2010 Census Records," Census Bureau, accessed April 21, 2012, http://www.census.gov/newsroom/releases/archives/american_community_survey_acs/cb07-cn05.html.

To reach a solution to these concerns, this research addresses the following fundamental questions:

- What are the efficiencies and costs of current space heating and cooling systems installed in most ECRHs?
- How can the ECRH historic and residential value be increased and the utility costs be decreased?
- What is the most viable space heating and cooling solution for a historic ECRH and how will it impact the homeowner in the long term?

The literature exploration and applied research design answers these questions and provides evidentiary support to the resultant belief that a GHP retrofit is an appropriate viable solution.

1.3 Methodology

This research document utilizes primary and secondary sources from certified government agencies, and published experts in the fields of architecture, engineering, and preservation. In addition, empirical case studies are examined and quantitative data extracted to validate or refute the secondary sources. The review of existing knowledge provides the foundation for the background and context of the ECRH and the heating and cooling dilemma facing homeowners. Most of the focus for this research is on the systems as it carries more applicability throughout the northeast where most ECRHs exist. However, the issues and solutions for cooling are also evaluated as they address the dual needs of historic ECRHs in particular that may not have modern air conditioning systems installed at all. Permit policies and regulation codes are explained as standards and constants that will be applied for any potential retrofit with additional emphasis on historic preservation requirement. An analysis of the GHP system usage, costs, efficiency, and investment benefits is compared to conventional space heating systems that exist in most ECRHs for a thorough investigation of the most viable options for homeowners. The knowledge and evidence from this research provides the grounds for first hand applied research in the form of qualitative regional expert interviews and a quantitative 3-D computer analysis case study. The results and findings qualify the evidence supported by the published literature and support the assertion of this study.

1.4 Research Organization

The following research document is organized in a progressive manner based around the research objectives whereby the questions are explored and answered throughout. Chapter 2 begins with an introduction to the history of ECRHs, the evolution of their space heating and cooling systems and the requirements to preserving and updating these structures to maintain and improve their value. The chapter continues into a summary evaluation of a residential GHP system and its applicability for use in a historic ECRH. The system is then compared to conventional utility sources predominant in the northeast that rely on oil, gas, and electricity fuel. A comparative analysis of the costs, efficiencies, and long term investment returns are evaluated for a full spectrum assessment of what homeowners are currently experiencing and what they can expect with a GHP retrofit. Published case studies conclude this chapter with examples of residential retrofits that support the evidence and data collected in the literature.

Chapter 3 summarizes the first hand applied research design conducted to qualify the literature review and data obtained in Chapter 2. The methodology, parameters, and results of the qualitative field interviews and the quantitative 3-D computer analysis case study is explained with supplementary raw data documentation provided in Appendix B. Chapter 4 provides the conclusive summary of the entire research for a final assessment and satisfaction of the research objectives.

2. EXTENDED LITERATURE REVIEW

2.1 The East Coast Row House (ECRH): Historic Overview and Evolution of Space Heating and Cooling Systems

The ECRH is one of the oldest residential structural forms in the United States whereby many of the original structures are still standing and functional. These homes reflect the history of our country and the progression of society over the past 250 years. The survival of historic ECRH communities is often dependent on preservation and rehabilitation. The recent trend for urban residential development is actually redevelopment or mimicking of older ECRH communities into modern versions of the same structures. These newer townhouse communities are often much quicker and cheaper to build, offer residences more desirable open floor plans, and utilize energy systems that meet the current gas and electric standards of this period. However, these residences do not meet the quality of materials and craftsmanship that will allow them the same longevity of 250 plus years, nor do they hold the prime central metropolitan footprints that shape our urban landscapes. The value of a preserved historic ECRH in the heart of a city center district such as Washington D.C. is upwards of $1 million compared to a new quick build townhome within a commuter friendly range valued at approximately $400,000.[7] These figures represent the lowest end of market value and can be almost triple if looking at areas such as Manhattan or Boston. This suggests that society still holds great value in owning and preserving history, yet in order to do that preservation must be maintained to adapt to the wear of time and changing needs of society.

As discussed, one of the greatest needs for historic residences is that of space heating and cooling, particularly in ECRHs that were designed and built to accommodate the resources of the past that are now costly and limited. Architect Baird M. Smith, AIA, agrees: “with the dwindling supply of energy resources and new efficiency demands

[7] These values are general estimates confirmed by appraised resale values listed on http://www.realtor.com/?source=webas, accessed February26,2013.

placed on the existing building stock, many owners of historic buildings and their architects are assessing the ability of these buildings to conserve energy with an eye to improving thermal performance."[8]

For ECRH preservation, it is important to realize that no house is exactly alike. The research below outlines the general history and period styles of historic row houses in cities such as New York, Philadelphia, Boston, and Washington D.C., whereby most can fit into a certain 'style' just by their facades. However, each one has had a different owner and resident for potentially 50 to 100 years or more. It is safe to assume that over such a long period time, almost every historic ECRH may have different renovations, internal changes, and utility systems to fit the needs of their changing inhabitants. For purposes of research summary, this document will also outline the evolution of space heating and cooling systems with the period styles to provide a probable assumption of systems that may exist in ECRHs in current need of rehabilitation and retrofit.

<u>Eighteenth Century - Nineteenth Century</u>

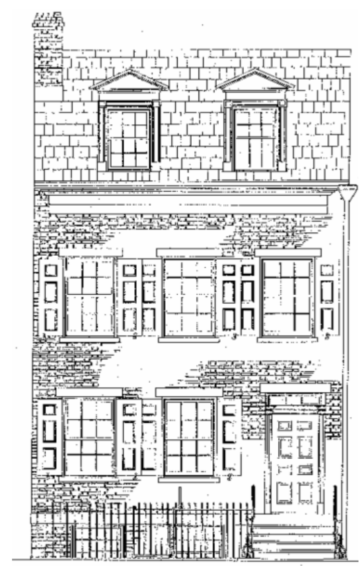
Figure 1

The oldest functional ECRH is the Federal Style (1770's – 1830's), originating during the American Revolution and derived from the English Georgian style. This early tradition was defined by minimal detail, little to no ornamentation, and red exposed brick. They were typically "two to three stories high with basement and attic half-story with dormer windows, [with] six-over-six double-hung windows" (see Figure 1).[9] Most Federal row houses "lacked a furnace and rarely had a cellar," they simply relied upon the brick masonry to absorb and reflect temperatures, or basic fireplaces if possible (Lockwood, 18).

In early American residential construction, methods and materials were selected based off availability in the environment and what made sense to manage hot and cold

[8] Baird Smith,"Conserving Energy in Historic Buildings," *Old House Journal*, accessed February 2, 2013, http://www.oldhousejournal.com/npsbriefs2/brief03.shtml.
[9] "Rowhouse Styles," New York City Landmarks Preservation Commission (NYCLPC), accessed April 7, 2012, http://www.nyc.gov/html/lpc/downloads/pdf/pubs/rowhouse.pdf.

temperatures. "In 1744, Benjamin Franklin designed his "Pennsylvania Stove" with a fresh air intake in order to maximize the heat radiated into the room and to minimize annoying smoke."[10] Window, doors, and overall floor plan design was also strategically placed to offer efficient ventilation. In many ways during the 18th century, "comfort level for occupants was low" but efforts were still made with these early structures to maximize material quality that still holds beneficial today. Many Federal ECRHs were also constructed with ship building wood that maintained balance between internal and external temperatures, and humidity to allow for expansion and contraction (Park).


Figure 2

The Greek Revival style (1830's – 1850's) highlights the urban row house construction boom and is marked by aesthetic ornamentation that became the priority for architectural design. This period is described as a "nationwide Greek Mania…that set a high standard of taste and opulence in city row houses perhaps unequaled anywhere in 19th century America" (Lockwood, 55). Structurally, Greek Revival houses were larger with three or more stories, a basement, attic, and "six-over-nine double hung wood windows" (see Figure 2).[11] This style grew to such an extent that it branched to non-residential buildings particularly in Washington D.C., where Greek Revival Architecture is and remains the distinctive feature representing American democracy. Internally however, energy systems were not far advanced as fireplaces were still the primary space heaters (*ibid.*, 75). The ceilings and walls are painted plaster that provided a pleasing appearance but are and remain sensitive to humidity and varied temperatures.

[10]Sharon Park,"Heating, Ventilating, and Cooling Historic Buildings: Problems and Recommended Approaches," *Old House Journal*, accessed February 2, 2013, http://www.oldhousejournal.com/npsbriefs2/brief24.shtml.
[11] "Rowhouse Styles," NYCLPC, accessed February 25, 2012 http://www.nyc.gov/html/lpc/html/home/home.shtml.

Figure 3 depicts the typical floor plans for an 1830's row house (*ibid*, 16). The front living room was used for entertaining guests with an adjoining kitchen room in the rear of the house. This layout configuration ranged between 800-3,000 sq. ft. depending on the number of floors. This particular floor plan had an extension off the back to allow for easy access to the backyard and extra storage space for the kitchen. Most notably the stairs along the side are a key trait that are standards for most historic row houses to make as much use of the center of the house as possible.

Figure 3

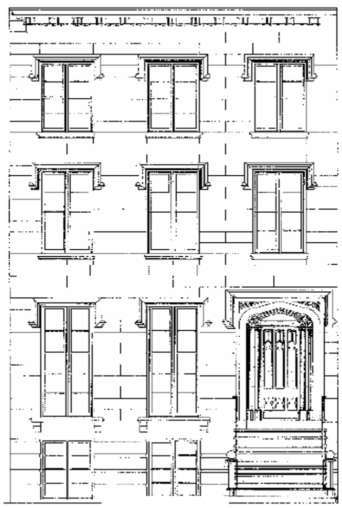
Figure 4

As a way to break apart from the norm, the Gothic Revival, Italianate, and Anglo-Italianate style houses (1840's – 1870's) emerged at the same time. The Gothic Revival (Figure 4) was inspired by "medievalism" and the "picturesque," with dark colored bricks, pointed dormer projects on facades, medieval ornamentation, prominent door hoods and multi-paned double-hung wood casement windows (Lockwood, 106; NYCLPC, 6).

The Italianate and the Anglo-Italianate contribute to this "brownstone" period with dark brick or stucco facades and heavy, "imposing" embellishments that repeat throughout (NYCLPC, 8). The Anglo-Italianate is much more noticeable style with the inclusion of arched doorways and elongated "two-over-two, one-over-one" rounded windows (Figure 5, *ibid*, 2).

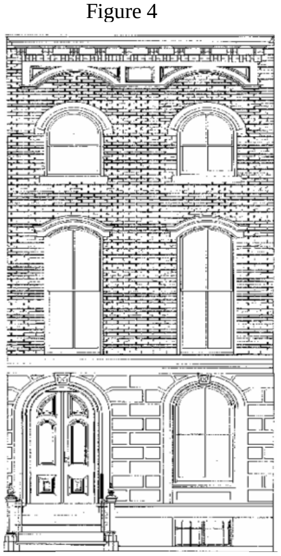
Figure 5

The Anglo-Italianate was also designed narrower and taller with three to five stories high and a basement. This change in structural design is a testament to the growth of industry and offered an efficient solution to the high demand of increased worker-tenants with decreased land availability and higher costs. According to the *Philadelphia Row House Manual*, “row houses outnumbered all other housing types… [and were a] cost-effective way to provide homes for a rapidly growing industrial city” (3).

The most notable contributions of the Nineteenth century to society and residential ECRH development were the technological advances derived from the Industrial Revolution. “The dual developments of steam energy from coal and industrial mass production made possible early central heating systems with distribution of heated air or steam using metal ducts or pipes” (Park). Not only were these materials being introduced into manufacturing development but it also led to the boom of ECRH development in city centers. With more manufacturing and plant jobs available to accommodate the exponential increase in material production, more workers required living quarters in proximity to their jobs. To fit more people required economical and efficient use of space over a small area.

<u>Nineteenth Century - Twentieth Century</u>

The Second Empire, Beaux-Art, Renaissance Revival, Neo-Greco styles (1860’s – 1980’s) vary in design and façade but share the common denominator of time. The designs remain popular for over 120 years, and with that unveil structural design continuity and predominance for most remaining ECRHs.

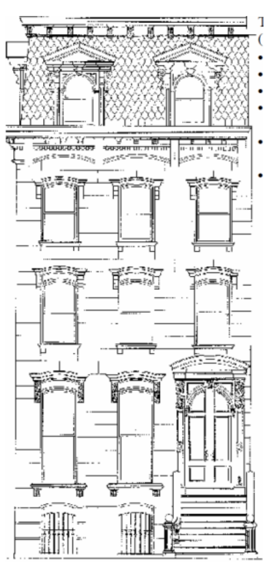

Figure 6

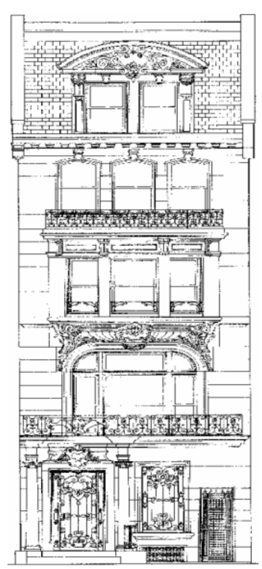

Figure 7

Figure 8

Figure 9

The Second Empire is similar to the Italianate but adds on more defined and detailed Mansard roofs (Figure 6, NYCLPC, 13). The Beaux-Arts incorporated richer materials of limestone and marble, ornamental iron work, large symmetrical windows with balconies, and a ground level entrance with no stoop (Figure 7, *ibid,* 3). The Renaissance Revivals reached back to simpler design, "restrained classicism, and academic expression," with wreath ornamentations around double hung wood framed windows (Figure 8, *ibid,* 11). The Neo-Grec style shows off industrial advances with mechanical stone cutting ornamentation, precision line incisions, and heavy cast-iron railings (Figure 9, *ibid,* 9). The Georgian Revival (1900's – 1920's) characterized by decorative Flemish bond include "alternating dark glazed headers (bricks with short ends facing out) and unglazed stretchers (long sides out) with prominent mortar joints," and steep gabled roofs.[12] Older Georgian styles follow Quaker influences marked by plain "shed" roofs and brick fronts while later Georgian designs include elaborate windows "bearing fancy scrolled consoles" and recessed doorways featuring columns decorative awnings (see Images 1 and 2 below).

Image 1

Image 2

[12] James Massey and Shirley Maxwell, "Row Houses of Society Hill in Philadelphia, Pennsylvania," *Old House Journal*, Accessed April 18, 2013, http://www.oldhouseonline.com/row-houses-of-society-hill/.

These genre of row houses incorporated more mechanically sophisticated heating systems into the buildings. “A coal burning furnace sat in the cellar in a brick vault about six feet by nine feet…wide wooden troughs brought outside air into the brick vault, where it (water) was heated by contact with the hot surface of the furnace and then (steam) forced through tin pipes to the upper floors"(Lockwood, 188).

This system of forced hot air brought with it great discomfort as the furnaces “actually sent up uneven blasts of scorching air, mixed with some gas and soot, rather than a pleasant, even flow" (*ibid,*189). Even with this new system, many of the row houses from this period still required coal grates in the fireplaces of upstairs bedrooms. “By late century, steam and low pressure hot water radiator systems were in common use...residential designs of the period often used gravity hot air systems utilizing decorative floor and ceiling grilles (Park). To improve the uneven forced air discomforts, power-driven fans were incorporated to the ventilation systems to allow more fresh air circulation throughout the heated and cooled spaces. With these advances however, the internal and external temperature differences were still minimal due in part to the lack of sufficient insulation for the building walls. Additionally, “the almost exclusive use of single glazed windows… and the reliance on architectural features, such as cupolas and transoms,” allowed for sufficient air movement but not a tight thermal envelope to secure internal from external temperatures (*ibid*).

The ECRH styles from the 19th century maintained throughout the urban centers of the 20th century as row house development slowed and suburban single family home development took over outside the city centers. The 20th century marked the improvements of utility systems and new types of building construction to once again accommodate the changing needs of society. World War II particularly inspired American development at home and the rise of large scale and towering metal structures. Post War rehabilitation and economic recovery from the depression fostered the need for stability and investment at home. Improvements in our construction and utilities included improvements in the 19th century oil and gas furnaces with electricity taking over as “the critical source of power for building systems in the latter half of the century” (Park).

Ductwork and registers evolved to allow the combination of heating and air conditioning in the same system that greatly improved architectural flexibility and comfort.

The need to save and become more efficient really took hold in the early to mid 20th century and smarter building insulation measures were developed to improve the thermal envelope of structures. “Synthetic materials, such as spun fiberglass batt insulation…insulated thermal glazing and integral storm window systems…[and] caulking to seal out perimeter air around window and door openings became a standard construction detail” (Park). The later part of the 20th century has focused on improving HVAC (Heating, Ventilation, Air Conditioning) efficiency throughout all residences. However, the quality of construction in the 20th century has fallen well below that of the past for quicker and cheaper material production, in fact “studies by the Energy Research and Development Administration show that the buildings with the poorest energy efficiency are actually those built between 1940 and 1975.”[13] Many of the historic ECRHs have been neglected in retrofits for efficiency due to their older structural materials being non-compatible with many modern HVAC systems due to factors such as humidity and lack of support strength. “Historic buildings are not easily adapted to house modern precision mechanical systems…[and] in too many cases, applying modern standards of interior climate comfort to historic buildings has proven detrimental to historic materials and decorative finishes” (Park).

As illustrated, the historic ECRHs are built with the most suitable heating systems of the period but unfortunately were not designed with intent of future upgrades or retrofits. The *Philadelphia Row House Manual* reports that currently “most row houses are heated by a boiler or a furnace that is fueled by natural gas or home heating oil” (34). These systems were introduced into ECRHs toward the end of the 19th century, and provide better comfort than the original fireplaces and coal forced air; however, even these systems are now viewed as extremely inefficient.[14] According to the Energy Information Administration (EIA) that provides the majority of statistical analysis and government accredited data on energy, “in 1960, 32.5% of US households heated with

[13]Smith, “Conserving Energy in Historic Buildings.”
[14]"Heating History," Sustainable Dwelling, accessed April 18, 2012, http://sunhomedesign.wordpress.com/2007/10/26/a-brief-history-of-heating-and-cooling-americas-homes/.

fuel oil, but only 7.9% in 2007…[while] electricity was used for heat in 1.8% in 1960, but 32.6% used electricity in 2007. Propane usage stayed the same, but natural gas heating has grown from 43.1% to 51.2%. Coal dropped from 12.2% to 0.1%."[15] This is a good snapshot of the residential transition of energy usage throughout the latter half of the 20th century. Most homes that relied upon non-renewable sources such as oil and coal have transitioned to more available resources of electricity and natural gas. These seemingly newer sources, as will be further discussed in this research, are also limited in their long term availability and are phasing out to more sustainable and renewable sources such as solar, hydro, and geothermal. Donal B. Lloyd, a geothermal homeowner, installer, and engineer makes the point, "if you have an older, aging oil or gas burner, you would be wise to consider a ground-source geothermal system… even homeowners who have fairly new oil or gas systems are retrofitting with geothermal heat pumps, due in part to the rising price of fuel and the possibility of having zero fuel costs in the future as well as the increased value of their home" (14). Despite the upgrades made over the years to transition homes to better efficiency, they are proving now to be just as detrimental because of the continued decline of non-renewable resources and the misalignment of the system with the functional needs of the house.

Commonly, ECRH renovations included heating system upgrades to oversized fossil fuel boilers/furnaces and water heaters that ultimately adversely affected the heating demands for a house by overproducing. A 3,000 sq. ft. row house with a boiler capable of producing enough heating for a 4,500 sq. ft. home created an on/off effect, causing the boiler or water heater to use more energy. In the *Solar Living Source Book* the author explains, "by far the most cost effective things you can do [is] downsize the furnace or boiler without compromising the capability of your heating system to keep you warm. An oversized system will be more to buy upfront and more to run every year, and the frequent short-cycle on and off of an oversized system reduces efficiency" (Schaeffer, 294). In older buildings, it takes "five to ten times as much energy" to space heat a home than provide hot water, further exposing the disadvantage these existing boiler systems create (Seifried, 44).

[15]Donal B.Lloyd, *The Smart Guide to Geothermal: How to Harvest Earths Free Energy for Heating and Cooling*, Masonville: Pixy Jack Press Inc., 2011.

Heating inefficiencies are not the only problem among older residences; the issue of cooling has played a major role as well. The advent of conventional air conditioning has only been around since 1902 and incorporated for residential use in 1914.[16] The first window ledge units were made available for purchase in 1931 and "only enjoyed by the people least likely to work up a sweat—the wealthy. (The large cooling systems cost between $10,000 and $50,000. That's equivalent to $120,000 to $600,000 today)" (Green). Depending on the part of the country where cooling in the summer months is needed most, most homes are either fitted with box window units or central air, however many ECRHs are not equipped since it was not part of their original design. The Residential Energy Consumption Survey by the EIA notes, "more older homes are adding window units or being retrofitted with central air conditioning… [while] air conditioning retrofits or upgrades are often financed separately from a mortgage, over a much shorter time period at higher interest, and may require capital improvements such as the addition of ventilation systems and ductwork."[17] So not only is it costly to upgrade with standard space heating systems, there is also the issue of cooling systems integration with the necessary reworking of ventilation. Particularly for historic homes requiring preservation, the potential for disruption is much higher. The EIA survey notes "about 91% of homes built since 2000 have a main space heating system that includes central ducts; for homes built before 1940, that number is just 50%."

Despite these energy inefficiencies, ECRHs are highly valuable due to their rich history, beauty, and functional space efficiency. However, the examples highlighted above demonstrate the need for current ECRH owners to re-evaluate the existing energy systems in their home, especially with the costs associated with conventional space heating and air conditioning upgrades. An energy audit is the best first step to assess the energy consumption of a home and evaluate what measures are needed to improve efficiency. These audits are often necessary before undertaking a retrofit and may be

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[16]Amanda Green, "A Brief History of Air Conditioning," *Popular Mechanics*, accessed February 13, 2013, http://www.popularmechanics.com/home/improvement/electrical-plumbing/a-brief-history-of-air-conditioning-10720229.

[17] "Air Conditioning in Nearly 100 Million U.S. Homes," Energy Information Administration (EIA), Residential Energy Consumption Survey (RECS) 2009, accessed January 28, 2013, http://www.eia.gov/consumption/residential/reports/2009/air-conditioning.cfm.

needed for the permit allowance.[18] Retrofits, especially space heating and insulation upgrades, will continue to preserve these historic homes and allow them to flourish well into the future.

[18] "Resources for Homeowners," Washington D.C. Historic Preservation Office (HPO), accessed April 15,2012,http://planning.dc.gov/DC/Planning/Historic+Preservation/Preservation+Services/For+Residents/Permits+for+Homeowners.

2.2 Regulations and Requirements for ECRH Efficiency Improvements:

Two of the most daunting reasons homeowners forego renovations or system retrofits is the fear of a renovation nightmare with faulty or unsafe results and high overhead costs. This reasonable concern is the justification for qualified architects and contractors that understand the safety regulations and codes to ensure the best results. Lack of knowledge and awareness among homeowners feeds this fear and is precisely why this research is a valuable contribution to the community. The standards provided by the International Code Council (ICC) "provide safe, sustainable and affordable construction, design, build, and compliance process," that are respected and enforced by all federal and state jurisdictions.[19] Additionally the *The Secretary of the Interior's Standards for the Treatment of Historic Properties and the Standards for Rehabilitation* include "separate standards for preservation, rehabilitation, restoration and reconstruction" for certified historic proprieties on the National Register of Historic Places.[20] Detailed in this research document are the specific policies and regulations relating to an ECRH retrofit that should be upheld for any ECRH retrofit project.

<u>ICC – IRC N1102.4.1 Building Thermal Envelope:</u>

The Building Thermal Envelope is made up of three critical building components: the floor, roof, and façade; subsequently, these are the main areas of concern for an ECRH with regards to insulation. The N1102.4.1 code applies to older ECRH that may not have a sealed envelope or possess an unsanctioned condition as this standard was not available at the time of build. Figure 10 below is a table provided by the International Code Council for International Residential Code (IRC) that defines the minimum and maximum building thermal envelope (ICC 11-4).

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[19] "About ICC," International Codes Council, accessed April 11, 2012, http://www.iccsafe.org/AboutICC/Pages/default.aspx.

[20] "The Secretary of the Interior's Standards for Rehabilitation on &Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings," U.S. Department of the Interior National Park Service, accessed January 11, 2013, http://www.nps.gov/tps/standards/rehabilitation/sustainability-guidelines.pdf.

TABLE N1102.1 INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION U-FACTOR	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[k]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE AND DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	1.2	0.75	0.35[j]	30	13	3/4	13	0	0	0
2	0.65[i]	0.75	0.35[j]	30	13	4/6	13	0	0	0
3	0.50[i]	0.65	0.35[e, j]	30	13	5/8	19	5/13[f]	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.35	0.60	NR	38	20 or 13 + 5[h]	13/17	30[f]	10/13	10, 2 ft	10/13
6	0.35	0.60	NR	49	20 or 13 + 5[h]	15/19	30[g]	10/13	10, 4 ft	10/13
7 and 8	0.35	0.60	NR	49	21	19/21	30[g]	10/13	10, 4 ft	10/13

Figure 10

The highlighted area of the graph, "Climate Zone 4," applies to the East Coast, particularly the Washington D.C. metropolitan area; the site of the research case study. The U.S. Department of Energy (DOE) defines this region as "Mixed-Humid: a region that receives more than 20 inches (50 cm) of annual precipitation, has approximately 5,400 heating degree days (65°F basis) or fewer, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months" (3). The important figures highlighted in Zone 4, are the R-Value minimums and the U-Value maximums that measure insulation efficiency and the heat leakage tolerances. The R-Value and U-Value numbers are inversely related so that a larger R-value denotes greater efficiency and a smaller U-Value conveys lower heat escape (*ibid*). The IRC states: "The *building thermal envelope* shall be durably sealed to limit infiltration [and] allow for differential expansion and contraction" (ICC 11-4). To accomplish this, 'all joints, seams, site-build windows, doors, skylights, utility penetrations, ceilings, walls, tubs and showers, common walls, and attic access openings,' shall be "caulked, gasketed, weather-stripped or otherwise sealed with an air barrier material, suitable film or solid material"(*ibid*). A thorough energy audit that can include blower door tests to measure air infiltration, and thermal imaging to identify heat movement are critical for understanding a home's actual envelope.

The history of ECRHs discussed the predominance of heavy masonry and brick walls that utilized dark red or heavy exterior paint that naturally improves thermal performance of the structure. This is one of the major factors why historic homes hold a higher construction quality to modern 20th century homes. “It has been determined that walls of large mass and weight (thick brick or stone) have the advantage of high thermal inertia, also known as the "M factor." This inertia modifies the thermal resistance (R factor) of the wall by lengthening the time scale of heat transmission.”[21]The brick or masonry acts a natural insulator retaining heat despite the colder exterior temperature and vice versa. The inherent efficiency of historic ERCH masonry is a key example of the benefits and value an ECRH already has and ultimately a huge preservation factor to limit the need for massive renovation or retrofit to improve its thermal envelope. Suggested methods to improve the thermal quality of a home, regardless of utility system is to ensure tight efficiency of the air infiltration systems, attic and basement insulation, doors and windows, and if required, internal wall insulation. The last is the most invasive with potential for greatest disturbance to the historic fabric of the house and should be professionally assessed before undertaking (Smith). According to Sally Zimmerman of the New England Historic Preservation Services, breaking into the wall insulation is a “more extensive solution than [a] problem may warrant, and its performance over time is still unknown.”[22]

No matter what kind of home, windows play a key role in heat escape from the interior. Window efficiencies are measured based on their U-Factor, ranging between 1.3-0.2, with the smaller value representing better performance as explained by the IRC.[23] Older row houses are typically equipped with single-pane glass and do not provide high thermal resistance. Instead, homeowners should consider upgrading the performance and durability of their windows themselves to at least a double-pane to maximize their space heating retrofit. Modern window technologies provide up to quadruple paning with gas

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[21]Smith,“Conserving Energy in Historic Buildings.”

[22]Katie Hutchison, “Energy-Efficient Retrofit at the Lyman Estate: An Energy-Saving Retrofit at a National Historic Landmark,”*Old-House Journal* (2013), accessed February 17, 2013, http://www.oldhouseonline.com/energy-efficient-retrofit-at-the-lyman-estate/.

[23]"Replacement Windows," Servicemagic, accessed April 11, 2012, http://www.servicemagic.com/article.show.The-U-factor-of-Thermal-Replacement-Windows.8839.html.

fills to block out cold air and let in warm rays of direct sun to warm the home interior. For even further protection from exterior weather elements and to increase efficiency performance, the installation of storm windows can be an alternative. These windows will "insulate against noise and drafts, to save on heating costs, and to protect primary windows from weathering" (NYCLPC). Homeowners should take caution prior to going to this step as permit requirements and approval may be required due to potential architectural aesthetic changes caused by storm window modifications.

Additional film options are also available for the pane's exterior to further increase the windows efficiency performance. For historic residences with restrictions on window change, film additions can be a helpful alternative. According to Steve DeBusk in his analysis of residential retrofits, "installing window film is a way to improve window performance by reducing solar heat gain to balance building temperatures, keep the heat out in summer and in during winter, reduce HVAC system load, control utility costs, and reduce glare...Most windows take approximately 15 minutes for window film application, with minimal or no disruption to building occupants."[24] This is especially ideal for historic ECRH with strict preservation requirements to preserve the original window structures. Window films are also inexpensive to install and range in price depending on the performance level. DeBusk cites ConSol, an energy consulting firm, assessing the return on investment for window film "ranges from 6% to 68% percent annually, depending on climate zone and the type of film." For colder climates as on the East Coast, that return will be achieved much quicker. Additionally, the window sash and framing of historic ECRHs were built specifically to the building making it important to "retain the original window configuration, including the size of openings, sills, lintels, decorative wood or masonry moldings, as well as the sashes themselves" for most preservation requirements.[25] Weather stripping is an easy way to stop drafts from loose or shrunken window sills and sashes, and can "increase energy performance by as much as 50 %" *(ibid).*

[24]Steve DeBusk, "Comparing Retrofits: Lighting, HVAC, Windows," accessed February 1, 2013, http://www.buildings.com/article-details/articleid/15262/title/comparing-retrofits-lighting-hvac-windows.aspx.
[25] "New York Row House Manual," 12.

Like windows, insulation is an important component and requirement for home energy efficiency. Figure 11 illustrates the actual percentages of heat loss in various areas throughout a historic row house.[26]

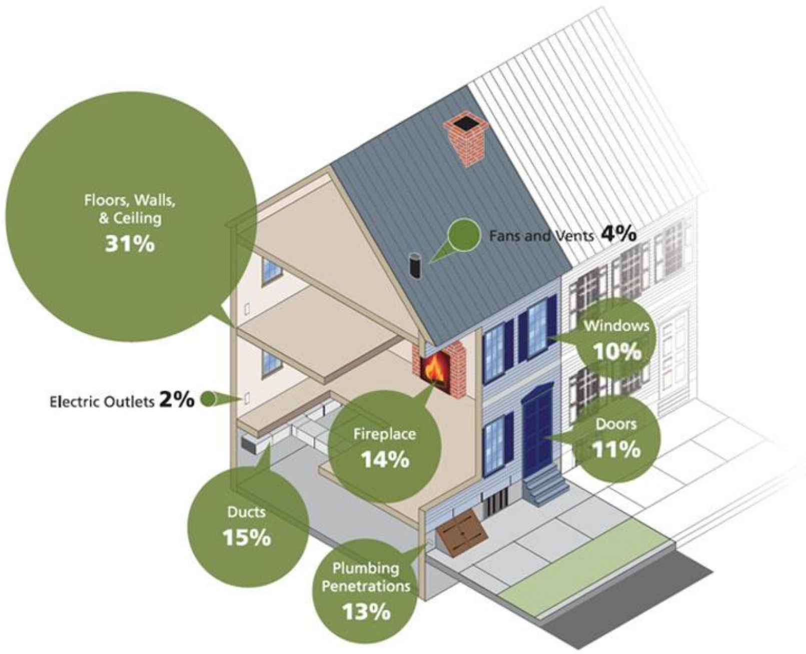


Figure 11

The most significant areas of heat loss include the floors, walls, and ceilings; components that can support insulation the best. This illustration is particularly insightful as most homeowner are unaware of this trend and are paying for it with their heating bill. The *Philadelphia Row House Manual,* further expounds on the typical wall insulation for historic Row Houses, explaining that the most common way to insulate is through metal or wood strips that stretch a vapor barrier on top and apply interior drywall (Figure 12). This vapor barrier is a composite material that prevents moisture from getting trapped inside the wall, thus preventing mold or pests.

[26]J. Hensley, and A. Aguilar, "Improving Energy Efficiency in Historic Buildings," National Park Service: 2011. p.5, accessed March 9, 2012, http://www.nps.gov/hps/tps/briefs/brief03.htm.

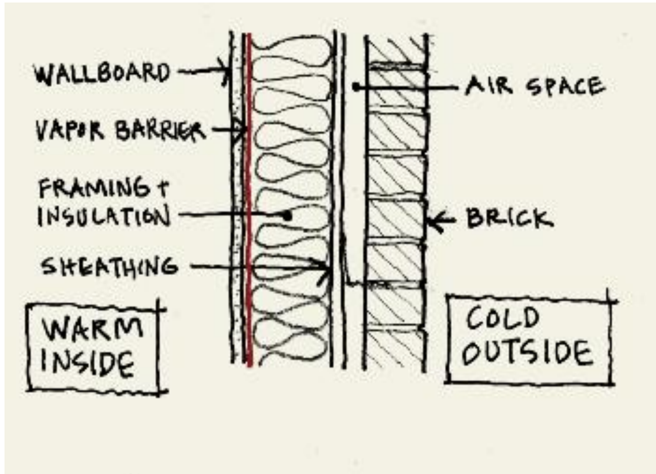


Figure 12

The heat loss occurring in the ceilings of row houses are due to side drafts known as the "Stack Effect" (Schaeffer, 52). Ron Judkoff, of the National Renewable Energy Lab, recommends “insulating at least to the level prescribed by the International Energy Conservation Code for Residential structures, but preferably beyond them." The benefit to these changes is that they require little disruption to the historic structure, and can have very minimal impact on the materials. The National Park Service (NPS) agrees, that "adding insulation in unoccupied, unfinished attics is not only very effective from an energy-savings perspective, but it is also generally simple to install and causes minimal disruption to historic materials."[27]

City preservation organizations such as The Washington D.C. Historic Preservation Office (HPO), provides education and permissions for homeowners desiring preservation renovations or retrofits. According to the D.C. HPO, owners must conduct a design review process that is assessed by the Historic Preservation Review Board (HPRB). For “most types of work” that involve interior or non-obtrusive façade work, the review process is “quick.”[28] Amanda Molson, a preservation specialist for the HPO responsible for the review of projects on Capitol Hill stated: “Because there are generally

[27]Hensley and Aguilar, “Improving Energy Efficiency in Historic Buildings.”
[28]“Resources for Homeowners, ” Historic Preservation Review Board, accessed April 25, 2012, ahttp://planning.dc.gov/DC/Planning/Historic+Preservation/About+HPO+&+HPRB/Who+We+Are/Historic+Preservation+Review+Board.

few HPO concerns about below-ground work on private property in historic districts, it is rare that geothermal heating raises historic preservation issues."[29]GHP requires minimal invasive disruption to the façade or architectural fabric of the home as majority of installation is below ground. The standard Department of Consumer and Regulatory Affairs (DCRA) limits of operation would include construction periods between seven am and seven pm, Monday through Saturday with no operation on Sundays.[30] Additionally, if the project is deemed "complicated," an Environmental Impact Screening (EIS) must be submitted and may take a minimum of 30 days for approval. The contractors and architects who are licensed and approved to work in this area are the main points of contact to acquire the required permits since they will be installing the system.

The Secretary of the Interior's Standards for Rehabilitation

If an ECRH is a registered property on the National Register for Historic Places then it will need to comply with the *Secretary of the Interiors Standards for Rehabilitation* that is ultimately reviewed by the local HPRB discussed above. To summarize, the standards ensure that historic properties are held to their intended historic purpose, maintain their character, and are protected from harmful changes that will shorten their longevity and preservation. Specifically, these standards now offer a section for energy retrofitting in the "Guidelines on Sustainability for Rehabilitating Historic Buildings" led by the National Park Service Branch of Technical Preservation Services. It recognizes "the fact that historic buildings are themselves often inherently sustainable and that this should be used to the advantage in any proposal to upgrade them" (Grimmer et al, v). With regard to retrofitting the HVAC systems, the standards recommend taking the whole buildings performance into account when installing an energy efficient system and placing equipment where it will be "minimally visible and will not negatively impact

[29] "Washington D.C. Historic Preservation Office," Historic Preservation Office, accessed April 25, 2012, http://dpw.dc.gov/DC/Planning/Historic+Preservation/About+HPO+&+HPRB/Who+We+Are/Historic+Preservation+Office/Staff+Biographies/Amanda+Molson.
[30]"Permitting Process Washington D.C.," Department of Consumer and Regulatory Affairs, accessed May 1, 2012, http://dcra.dc.gov/DC/DCRA/Permits/Get+a+Permit/Get+an+Overview+of+the+Permitting+Process?detailBean=contentBean.

the historic character of the building or its site (*ibid*, 12). The standards also specifically reference GHP as a recommendation with the caveat to ensure the system will enhance the heating and cooling efficiency before installation and not disturb archeological resources in the landscape. This will require a professional energy auditor to assess the potential efficiency improvement as well as an archeological investigation of the landscape.

Overall, the only way an ECRH retrofit or preservation of any kind can be properly employed is through homeowner education and research. It cannot be overstated the importance of invested time to ensure the right qualified people are doing the work and proper regulations and codes are upheld in order to maximize the investment made to ensure value of the home. Homeowner confidence is key and “the realization that fully 30 % of all construction in the United States now involves work on existing buildings, will stimulate the development of new products that can be used with little hesitation in historic buildings.”[31]

The following section outlines one of the most efficient space heating systems competitive in the market today. The facts extracted from the literature and explored in this section lend credence to the Geothermal Heat Pump (GHP) as the most viable space heating system for an ECRH retrofit.

[31] Smith, “Conserving Energy in Historic Buildings.”

2.3 Energy Efficient Heating System: Geothermal Heat Pumps (GHP)

The main energy systems included in the alternative, renewable, and sustainable categories are solar, wind, hydro, and geothermal. Solar in particular has had a major surge of popularity and integration among homeowners in the recent years. Geothermal has been slow to progress into social and residential consciousness because of the general lack of information and public awareness. Donal B. Lloyd summarizes, "Ground based geothermal heat pumps are underutilized because they are not well known or are misunderstood… lack of consumer knowledge and/or confidence in the GHP systems benefits is one of the key barriers to the growth of the GHP industry "[32]He also notes that in a general survey only two out of ten people knew what a geothermal heat pump is while nine out of ten knew of a solar panel (*ibid*). The best solution to this problem is continued research such as this that highlights the function, cost and comparative analysis to conventional systems that can assist homeowners and the public in making informed decisions.

What is puzzling about the lack of general geothermal knowledge is the fact that the system was developed back in 1852 by Lord Kelvin.[33] Kelvin debunked the idea that heat only moved downward away from cold. It was not until the 1940's that Robert C. Webber performed personal experiments and applied the geothermal principles to his residence utilizing his freezer. He found that as his freezer kept items cold on the inside, it was expelling heat that was being wasted and could be harnessed for redistribution to other areas of his home (IGSHPA). He took it even further by placing 'copper tubing with freon gas into the ground to gather the earth's constant subterranean heat.' It was not long after that the commercial industry caught hold, whereby in 1946, "the first successful commercial installation of ground-source heat pumps for climate control was [utilized in] an office tower in Portland, Oregon."[34] Since then, geothermal systems have

[32]Lloyd, "The Smart Guide to Geothermal," p. 26.
[33] "About Us: History," International Ground Source Heat Pump Association (IGSHPA), Accessed January 17, 2013, http://www.igshpa.okstate.edu/about/about_us.htm.
[34]Lorraine Kreahling, "Digging Up Energy Savings Right in Your Backyard,", *New York Times,* (2011), accessed January 17, 2013, http://www.nytimes.com/2011/03/08/science/08geothermal.html?pagewanted=all&_r=0.

been incorporated throughout the world in some of the largest industrial and commercial companies such as "Google, SAP, and Halliburton."[35]

2.3.1 Function, Components, Usage

Function:

A GHP, also known as a “Ground Source Pump” or a “Geo-Exchange System,” is a coupled loop system of vertically or horizontally laid pipes that extract heat from the earth and pump it into a home or building. Like a refrigerator, GHP also removes heat energy from the interior of the house during the summer months and pumps in cool energy from the ground to cool the home. GHPs can be categorized by function, heat source, and fluids used to collect and distribute the heat. Figure 13 below depicts how the GHP system works for a home.[36]

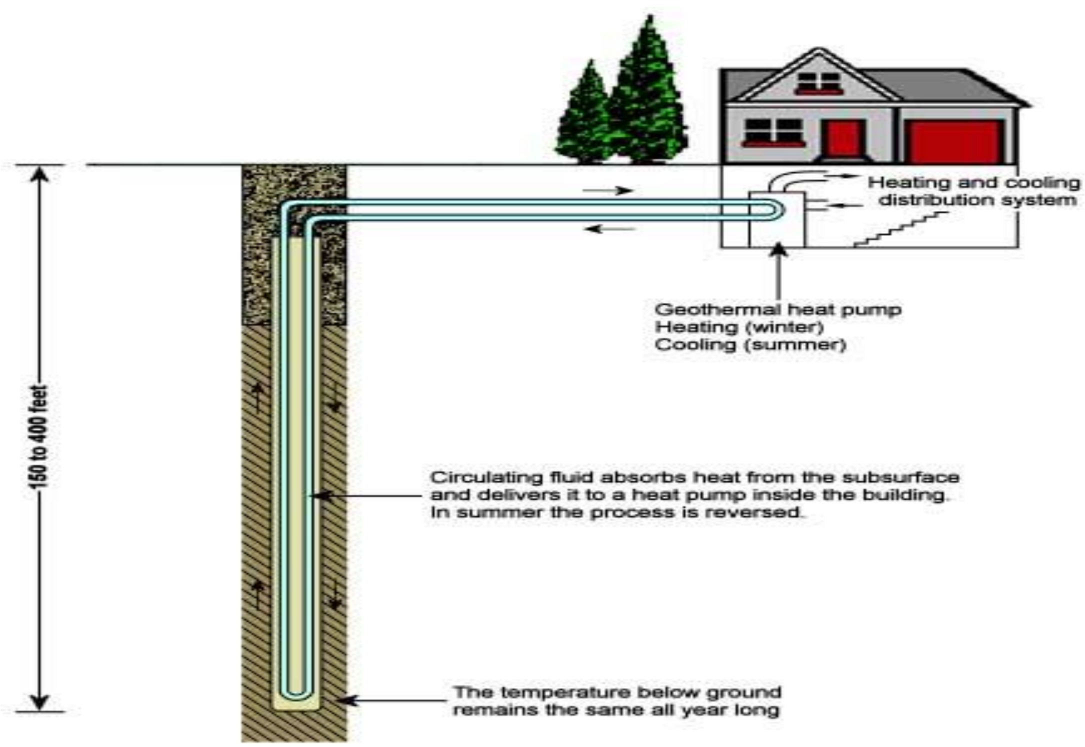


Figure 13

[35] Charles Goulding et al., “The Energy Tax Aspects of Geothermal Heat Pumps," accessed December 2010, www.energytaxsavers.com/articles/geothermal.
[36] "Heat Pump Diagram," accessed April 12, 2012, http://howdoesaheatpumpwork.net/.

Approximately three meters below the ground surface, the earth maintains a temperature between 10 and 16 degrees Celsius, regardless of the season (Galloway, 93; Smith, 48). The best soil conditions to accommodate these temperatures are loose soils that allow for air and water to penetrate through the well systems and provide better heat transfer.[37] For a typical residential geothermal system, at least 400 feet of polyethylene pipe, filled with an "environmentally safe" mix of water and anti-freeze, laid in a U-configuration between 150 to 450 feet deep, extracts the ground heat where it is amplified to a suitable temperature by an electrically powered heat pump (Galloway, 94; Smith, 48; Stein, 370). Electricity excites a compressor inside the pump that intensifies the output heat at a rate "three to four times more efficient than using electric resistive heat" (Galloway, 94). For most GHP systems there are a series of three functional loops: the ground loop, the refrigerant loop, and the air loop.[38] Dependent on where these loops are placed, what materials and components are used, and in what configuration is determined by the type of GHP system installed. The section to follow briefly describes the categories of GHPs and how they each function to outline the full spectrum of geothermal potential.

Components:[39]

The typical system utilized in residential Geothermal is the *direct expansion to water* heat pump. The loop of pipes and the brine inside are in direct contact with the ground or a body of water be it a lake or a swimming pool. This setup circulates latent heat from underground which provides a high performance of efficiency. The heat that is acquired is then compressed to adjust to the desired temperature for home use. This system does not utilize a heat exchanger which allows the resultant heat to directly populate the house.

Direct expansion to direct condensation is a similar method however it goes through a heat exchanger, conditioner and boiler, that requires more operational components but allows more usage for additional heating to radiant floor systems and hot

[37] "Soil Types: Heat Pump Vs. Air Conditioner," accessed May 3, 2012.http://heatpumpvsairconditioner.com/the-best-soils-for-ground-source-heat-pump-installation/
[38] Lloyd, "The Smart Guide to Geothermal," p.46.
[39] "Geothermal Heat Pumps," accessed February 11, 2013, http://www.earthscan.co.uk/?tabid=415.

water supply. The heat exchanger is typically a set of coaxial copper pipes that contains a cool refrigerant that "accepts heat energy and becomes a gas as it heats up" (Lloyd, 47). The excess heat produced is superheated through a compressor and released through an expansion valve in its highly pressurized form to populate the heating systems. Meanwhile, the refrigerant returns to its cooled state and circulates back through the system to pickup more heat to repeat the process.

[40]

Figure 14

Figure 14 above, depicts the *direct expansion to direct condensation* ground laid geothermal loops filled with a water/brine combination carrying latent heat from the earth to an optional storage tank. The heated fluid is pumped into the heat exchanger and compressor where it is super heated and shot to the conditioner and boiler for additional supply to the radiant floor heating and water supply.

Another method for GHP is an *air to water heat pump split unit* that uses two systems to work in cohesion to create the heat for the home. An outdoor unit (compressor/evaporator) is connected to the ground laid geothermal loops through

[40] "Ochsner Heat Pumps," accessed February 19, 2013, http://www.ochsner.com/anlagenplanung/waermequellanlage/anlagenplanung-direkterwaermung/.

refrigerant lines. The unit also takes in the ambient air to supplement the movement and compression of the geothermal latent heat obtained from the ground.

[41]

Image 3

Image 4

Image 3 and 4 identify the hoses that funnel the heated fluid from the geothermal ground laid pipes into the outdoor unit where the solution is compressed and evaporated for further flow into the house. The compressed heat is filtered into the indoor unit where it undergoes heat exchange with hot water and pumped to the homes heating system (see Figure 15 below).

[42]

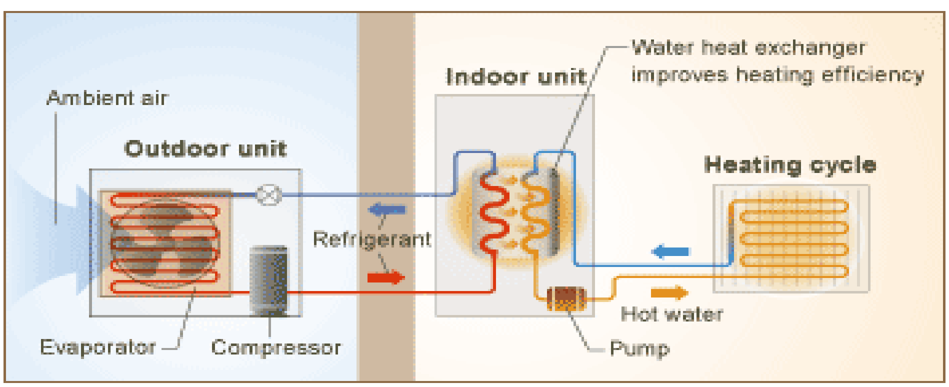


Figure 15

[41] Photos taken by researcher, Carlos Lopez, at the residence of Scott Sklar, Arlington, VA, February 8, 2013.

[42] "Fujitsu General: Air to Water," accessed February 19, 2013, http://www.fujitsu-general.com/global/products/atw/index.html.

43

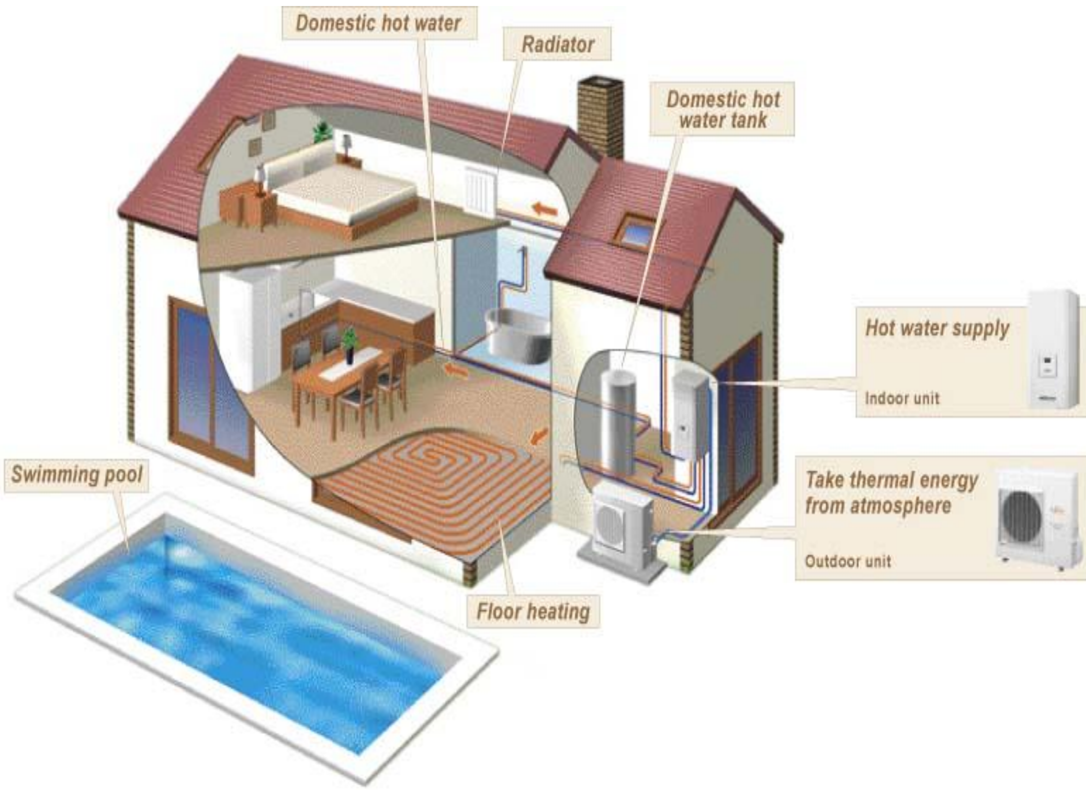


Figure 16

Figure 16 above depicts the full internal operation of a *split unit geothermal systems* where the radiator space heating, radiant floor heating, and hot water supply are all supported by the system. One of the key aspects to the split unit system is the non reliance on ductwork because the heat is supplied straight to radiant heat systems. This is an option for historic homes that may have restrictions or inability to retrofit the existing ventilation systems.

The alternative to a split unit is a single *water heat pump unit* that houses all of the components (compressor, heat exchanger, and the pump) in one consolidated box that can be installed indoor or outdoor. All of the supply pipes are installed underground along with the power supply and control cables. This system directly supplies the warm

[43] "Fujitsu General: Air to Water," accessed February 15th, 2013. http://www.fujitsu-general.com/global/products/atw/index.html.

or cold output to the space heating system and any other systems desiring use the heat supply.

[44]

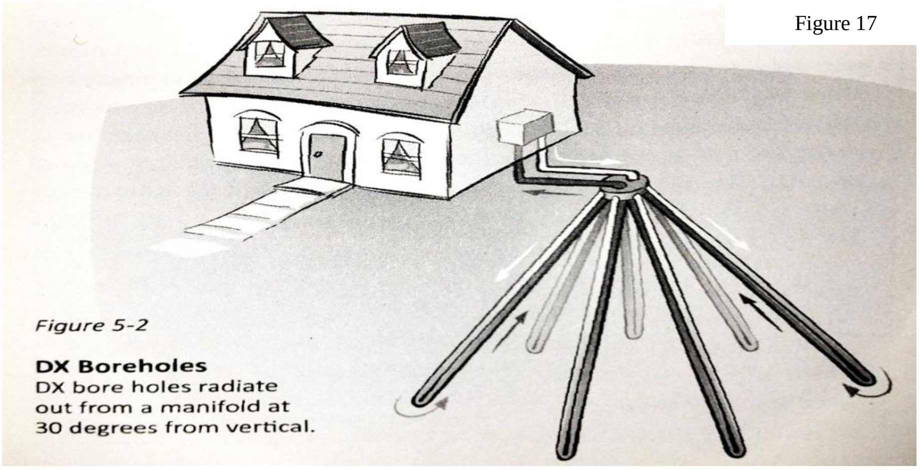
Image 5

Image 6

Images 5 and 6 above show a water heat pump housed outside of the house with an access maintenance door nearby. The insulated black pipes receive the geothermal supply and forward the resultant heat output into the internal heating units.

Considered one of the newer and most efficient methods of utilizing geothermal is the *Direct Exchange (DX)* system. This system is different in that it uses the refrigerant directly in the ground laid pipes to expedite the heat exchanging process while in the ground (Lloyd, 62). The ground laid tubes are copper instead of plastic which is sealed by grout to prevent any leakage into the earth. The pipes are also laid differently at "30-degree angled shaft, each less than 3 or 4 inches in diameter" (Figure 17).[45]

Figure 17



[44] Photos taken by researcher, Carlos Lopez, at the residence of Scott Sklar, Arlington, VA, February 8, 2013.
[45] Lloyd, "The Smart Guide to Geothermal," p.65.

This system is approximately 30 percent more efficient than the other geothermal systems because it uses the high pressure refrigerant to pick up the earths latent heat directly, eliminating the need for additional heat exchanger units. It does however require more copper piping and refrigerant which can add cost to the overall system. It is also imperative that it is installed by an experienced professional as the directly exposure of the refrigerant to the ground via a leak or pipe breakage could be extremely costly. Thankfully as technology continues to advance, many eco-friendly refrigerants are available and the systems typically come with a 50 year warranty should any problems occur (*ibid.,* 66).

Usage:

The internal output temperatures provided by GHP are adjustable with a thermostat and can achieve a max range of 90 to 104 degrees Fahrenheit.[46] The comfort level is maintained through an even distribution of circulating forced air. This method allows for thorough heating for the entire home and prevents cold or hot spots and blasts of dry air. Additionally, because the air is circulatory, energy usage remains relatively fixed at the standard operating level. GHP also provides an option for radiant floor heat that provides warm temperatures on the floor, allowing owners to experience the direct heat on contact as explained in the component section above.

In addition, GHPs have the unique benefit of temperature reversal where it can provide both heating and cooling, "for the same cost as a conventional central heating system" (Smith, 48). The only difference for the summer cooling mode is the use of a reversing valve and compressor that pushes the warm water down into the cooled earth where the refrigerant mix acts as a heat exchanger and becomes a "cold gas after passing through an expansion valve" for use as conditioned air (*ibid.*, 50). Figures 18 and 19 below depict the basic temperature exchange between seasons.[47]

[46]"Geothermal Heat Comforts: Thermal Comfort Benefits with Geothermal Heating," Carolina Heating Services Inc., accessed April 25, 2012.http://carolinageoheating.com/geothermal_faq.php.
[47] "Geothermal Heat Pump Diagram," Montara Ventures, accessed April 9, 2012, http://montaraventures.com/blog/2008/01/15/geothermal-heat-pumps/.

[48]

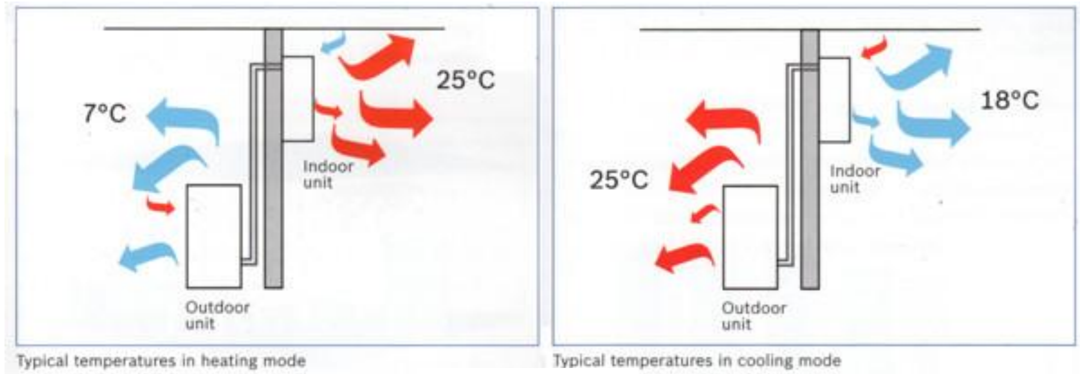


Figure 18

[49]

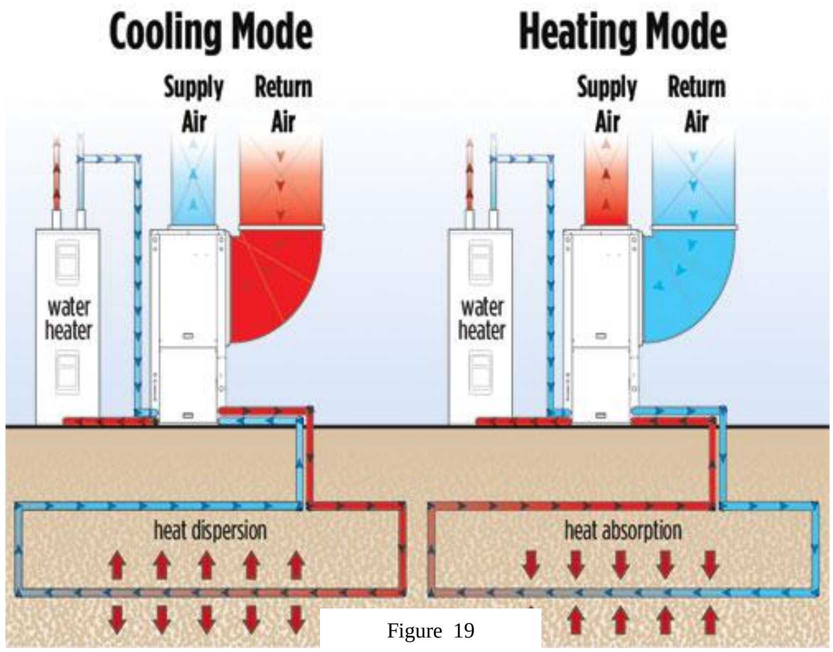


Figure 19

In both the heating and cooling modes, GHP maintains a suitable level of moisture by maintaining "about 50% relative indoor humidity" (Cooling Comfort). The summer months on the East Coast can range from 90 to 100 degrees Fahrenheit, therefore the GHPs minimum output temperature of 50 degrees Fahrenheit allows for an acceptable cooling comfort for the home.

According to the EIA, most homes either utilize central air conditioning systems or box/room conditioners, mostly dependent on the climate region. Table 1 compares the common air conditioning systems within the four standard regions of the United States.

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[48] "Heating and Boilers: Air to Air Heat Pumps," accessed February 19,2013. http://www.heatingandboilers.co.uk/renewables/air-to-air-heat-pumps/.

[49] "Cooling Comfort," accessed May 1, 2012,http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=126.

	Northeast	**Midwest**	**South**	**West**
Of homes that use AC, percent that use.....				
Central AC equipment	44%	76%	85%	74%
Window/wall AC units	58%	26%	16%	27%
*Some homes have both central and window/wall AC, so totals will add to more than 100%				

[50]

Table 1

The information from this table is telling in that majority of the Northeastern homes utilize room conditioners which reflects the age of most homes since less than 50% of older homes have integrated central air conditioning. According to the EIA, "variation within regions can be dramatic: 69% of air conditioned homes in New Jersey use central equipment compared to 28% of homes in neighboring New York. This difference is largely due the different mix of housing types and age of housing stock between the two States" (EIA, "Air Conditioning"). New York, one of the oldest states in the union, has a predominance of older residences and the highest population of historic ECRHs.

The dual function of GHP greatly alleviates the necessity for two different energy system upgrades into a home. As discussed earlier for the ECRH, one system that can comfortably perform the function of heating and cooling would have less invasive impact on the home and be much more affordable in the long run, especially when compared to the integration of central air conditioning in an older home. From the information in Table 1, homes in the Northeast would greatly benefit from a combined system that can provide the comfort and luxury of central air in one combined heating and cooling system.

[50] "Air Conditioning in Nearly 100 Million U.S. Homes."

2.3.2 Installation

One of the major aspects of GHP is that it is discreetly installed underground without the need to re-excavate for maintenance and can literally be 'out of sight, out of mind.' In an New York Times article, the executive director of the Geothermal National and International Initiative puts this concept into perspective: "you see solar panels up on a roof and wind turbines on the horizon...but if your neighbors missed the day the drillers were in your backyard putting in wells, they don't know about your green heating system."[51]

The first step prior to taking on any retrofit project is to have the home assessed, especially the surrounding environment in the case of alternative energy systems. The National Renewable Energy Laboratory (NREL) recommends you consider the" historical activity of the local geothermal industry," and compare the local geothermal designers, installers, and HVAC contractors who would potentially install your system.[52]

The GHP system is concealed and non-intrusive below the ground. The type of ground material can play a factor in the drilling process but typically, a mixing of rock or clay is beneficial as it provides firm well walls that limit chances of erosion over time. GHP is not reliant on fluctuating sunlight or ambient temperatures, and would not require a supplemental heating source, other than standard electricity in order to fully operate. In fact, the "Geothermal Heat Map" (Figure 20), depicts the overall subterranean temperature average for the continental United States, with the east coast yielding the ideal GHP temperatures between 47-63 degrees Fahrenheit (9-17 degrees Celsius) annually.[53]

[51]Kreahling, "Digging Up Energy Savings Right in Your Backyard."
[52]"Geothermal Policymaker's Guidebooks Assess Local Industry and Resource Potential for Geothermal Electricity Generation," National Renewable Energy Laboratory (NREL), accessed January 27, 2012 http://www.nrel.gov/.
[53]"Geothermal Heat Map" GHP Technology, accessed April 1, 2012, http://www.geo4va.vt.edu/A1/A1.htm.

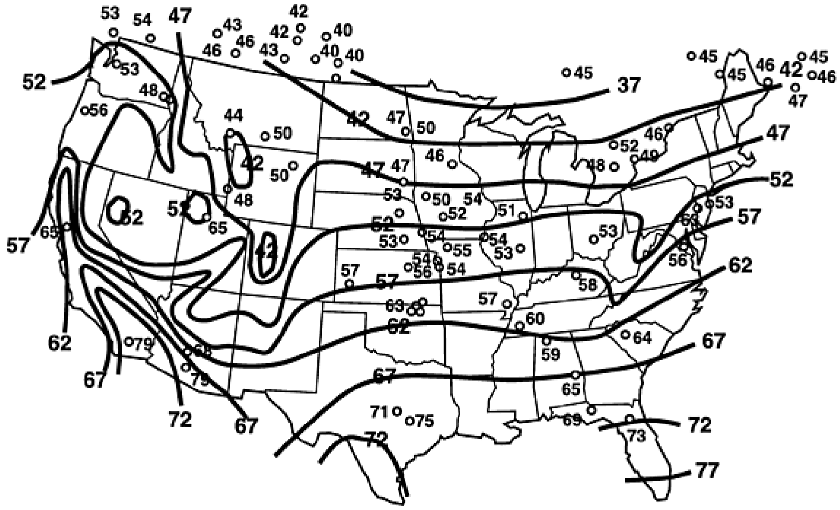

Figure 20

The installation of the pipes is achieved through drilling that requires minimal area around the ECRH. These homes vary in the amount of green area around the structure and may not have yards at all. To achieve this, drilling equipment come in several options to accommodate tight working areas. The most appropriate type for an ECRH is a compact drill system that is “2-4 times faster than conventional drills."[54] The drill in

Figure 21

Figure 21 is the B37 Model, it measures 6'W x 10'L (when mast is in place) and can be moved by electronic controls and a diesel mounted engine for enhanced maneuverability.

The compact size allows for quick excavation thereby reducing the installation time. ECRHs with little to no yard space can still utilize compact drills by entering via the sidewalk at an angle to achieve a proper depth.[55] An appropriate drill for that is the K40 from "Rigkits," that can reach 600+ ft. in depth and is able to penetrate through rock to reach its projected depths.[56] Shown in Figures 22

[54]"Compact Drilling Equipment," accessed April 26, 2012, http://www.mobiledrill.net/.
[55] “IGSHP Association,” accessed April 30, 2012, http://www.geoexchange.org/.
[56]"Compact Drilling Rig," accessed May 1, 2012, http://www.rigkits.com.

and 23, the width of the machine measures only 34" wide and with its retractable legs can extend up to 52" inches to stabilize the rig once in position to begin drilling.


Figure 22


Figure 23

Similarly, the PRD 450 Portable drilling rig works well in side alleys, throughways and tight rear accesses for less accessible yards (Figure 24).[57] This version allows users to dismantle and reassemble the drilling rig to move in between the tight row house spaces. The capabilities of this rig can reach down to 500 ft. with the use of a diesel power engine but may take more time to drill over the other compact drill systems.


Figure 24

[57] "Portable Drill Rig" accessed May 1, 2012, http://prdrigs.com/.

Physically, the drills create the geothermal wells by feeding “drill string” metal tubes over the rotating drill bits that bores deeper into the earth.[58] “Drilling mud” is filtered down through the tubes to cool and lubricate the drill while carrying away excess rock and excavated material (Figure 25).

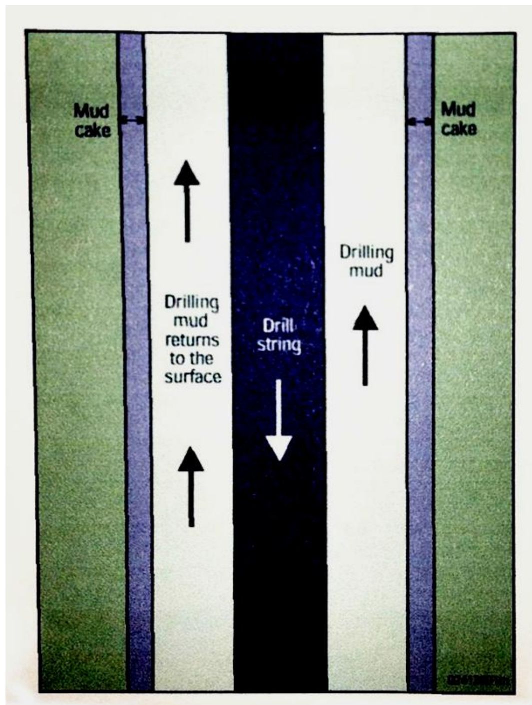

Figure 25

Trenchless horizontal bore loops are a feasible solution to urban areas that require wells drilled through narrow streets or sidewalks. "Using special equipment...the operator directs the machine drill at a slight angle...using the right technique, he/she can "steer" the drill head to go deeper or shallower, or turn right or left" (Lloyd, 57). As discussed with DX systems that are installed from a single pivot point, the copper pipes extend at 30 degree angles from one ground entry point.

[58] “Drilling,” Department of Energy Office of Geothermal Technologies, March 1998.

2.3.3 GHP Summary

The dual-functionality of a GHP is a great benefit allowing homeowners to use one system to do the job for both heating & cooling. According to Dieter and Witzel's book, "The Facts," GHPs "would save many billions of kilowatt-hours of electricity and heat in homes…but this change would require decision makers to be better informed and trades people to be better trained" (30). The electricity savings the authors refer to is the fact that GHPs can deliver more "free" heat energy than the electrical energy the system uses to function (Stein, 367). With increased education and awareness from research such as this, a home's electricity bill will decrease, gas or oil needs for space heating will be reduced, energy will be conserved, and the overall efficiency and cost savings will drastically improve.

Discussed earlier in this section, geothermal systems are relatively unknown to the average U.S. homeowner. However the Chief Operating Officer for the Department of Energy Efficiency and Renewable Energy Office states "the 115,442 heat pumps that shipped from manufacturers in 2009…was triple the number from a decade earlier" and that "3.5 percent of homes built that year installed geothermal heat pumps."[59] On a larger scale, in 2005, there were over 1.3 million geothermal installations worldwide and in 2008 that number was assessed to have increased to more than 2 million in more than 30 countries.[60] Donal B. Lloyd pointed out earlier the lack of knowledge as the downfall to GHP growth followed up that statement with the assertion that "this technology has been slowly perfected over the last 50 years to the point where GHPs are now slowly becoming mainstream technology for domestic heating and cooling, and indeed for commercial and institutional installation."(15).

Despite the slow growth, GHP awareness is on the rise and there are no disputing claims found that challenge the facts presented in this section. GHP is a renewable dual functioning space heating and cooling system, with discreet installation that requires

[59] Kreahling, "Digging Up Energy Savings Right in Your Backyard."
[60] "Geothermal Heat Pumps," accessed January 23, 2013, http://www.earthscan.co.uk/?tabid=415.

minimal maintenance and moving parts while independent of external factors in order to operate. The following section analyzes the usage and installation costs associated with GHP which is the area of highest criticism for this system.

2.4 GHP Cost Analysis: Installation and Usage

For every dollar the typical family spends on home energy, almost half goes to heating the home; and for every degree a thermostat is turned down, heating costs are reduced by three percent" (PRHM, 41). To highlight the financial dilemma further, "heating and cooling a home typically accounts for more than 40 percent of a family's energy bill (as much as two-thirds in colder regions) and costs an average well over $800 a year".[61]

Installation Cost:

Conducting a GHP retrofit into an ECRH will not be an overnight process as there are zoning and permit requirements, site analysis, excavation, and installation procedures. These necessities primarily come with the cost of time, professional fees, and equipment that should be proportional to the level and quality of work for the overall project cost (Gwok, 132). The DOE recommends using a high-efficiency "EPA Energy Star" approved system to ensure it rates at least "2.8 COP (Coefficient of Performance) and 13 EER (Energy Efficiency Ratio).[62] Depending on the space requirements in the home, especially for an ECRH, GHPs are flexible in shapes and sizes ranging from "from ½ ton to 30 tons [and] can be located in a closet or in the occupied space."[63]

According to the DOE and the Geo-Exchange Organization, the "average residential GHP system installation cost is currently $20,000, depending on building size, heating and cooling load, drilling costs and other factors," while the National Association for Home Builders averages $11,000.[64] These are hefty price tags for a single system, however when compared to other utility systems and the fact that geothermal is dual

[61]"High Heating Oil Costs, "*New York Times*, accessed April 15,2012, http://www.nytimes.com/interactive/2012/01/22/business/energy-environment/high-heating-oil-costs-hurt-more-in-northeast.html?ref=business.
[62]"Energy Savers," Department of Energy, accessed April 15, 2012, http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12670.
[63]"Geothermal Heat Pump Design Manual," McQuay International, 2002, p3, accessed April 15, 2012, http://planning.dc.gov/DC/Planning/Historic+Preservation/Maps+and+Information/Policies+and+Procedures/Preservation+and+Sustainability/Geothermal+Heat+Pump+Design+Manual.
[64] "Geothermal Heat Pumps," NAHB Research Center, accessed April 15,2012, http://www.toolbase.org/TechInventory/techDetails.aspx?ContentDetailID=754.

heating and cooling, this figure is equitable and overall less expensive due to post incentives and efficiency returns. Currently the average cost of a low end gas/oil heater without cooling properties or “Energy Star” approval is between $4,400-$5,200 not including the actual installation if proper infrastructure is not up to code.[65] To install central air, especially in an older home without the required duct work the cost can range between $2500-$15,000 depending on the size and amount of work needed for installation.[66] It is recommended by the EIA to “retrofit homes with new, more efficient air conditioning equipment that would reduce annual cooling costs to households.”[67] Looking at these two separate systems combined, a homeowner can easily spend upwards of $15,000 for two separate systems when the investment in a single dual operating system such as GHP would pay back dividends in the long run. Eric Woodroof, Ph.D, CEM asserts the challenge of higher GHP cost due to installation but explains, “the ground loop will last more than 50 years, so perhaps utilities should treat this as “infrastructure” the same way that they evaluate transmission lines. In addition, because these systems last 50+ years and we pay the operating costs every year, the life-cycle costs should be compared.”[68] It is important to note that utility upgrades and retrofits are overall investments to the wellbeing and property value of the home, just as it would be to a commercial or industrial structure to ensure overhead infrastructure costs will result in a profitable return on investment. This comparison will be addressed further in this document in the GHP Benefit Analysis section.

In addition to discreet installation, a great advantage of GHP is it requires non-invasive maintenance for the homeowner and smaller spaces than other HVAC systems (McQuay, 5). The DOE confirms that GHP systems have “relatively few moving parts, and because those parts are sheltered inside a building they are durable and highly reliable…the underground piping often carries warranties of 25-50 years, and the heat

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[65]"Dottery's Plumbing and Heating," Dottery's, accessed April 22, 2012, http://www.dotterys.com/services.php.
[66]“Central Air Conditioning Installation Cost,” accessed January 26, 2013, http://www.fixr.com/costs/central-air-conditioner-installation.
[67]“Air Conditioning in Nearly 100 Million U.S. homes.”
[68]Eric Woodroof, “Drill, Baby, Drill! Geothermal Energy,” accessed February 9, 2013, http://www.buildings.com/articledetails/articleid/13555.aspx?title=drill,%20baby,%20drill!%20geothermal%20energy.

pumps often last 20 years or more." [69]This is a huge incentive for homeowners who do not have the time or funds to apply toward monthly or yearly maintenance. The most frequent upkeep will be similar to a home air conditioning unit requiring filter and coolant changing on a periodic basis. GHP is also equipped with "double-sloped, cleanable drain pans and closed cell insulation" to control moisture and maintain proper indoor air quality (McQuay, 5).

Usage Cost:

Unlike installation costs, usage costs are an aspect of GHP that has minimal challenge particularly when assessed by its full range of functions. The U.S. Department of Energy (DOE), with the assistance of Les Bluestone of Blue Sea Development Company in New York, has found that for those that have installed or are considering retrofitting with GHP the opinion is, "even if you pay more up front, the good news is you are likely to pay less for an energy-efficient house on a monthly basis, if you consider the cost of energy…If you can save $1,000 a year on heating bills – to someone who is making a 4 million a year, this doesn't mean much. But to someone who is making $30,000 to $40,000, this is a big piece of change."[70]Supporting this claim, the National Association of Home Builders assess that homeowners would be open to spend "$5000 more on a new home if it saved them $1000 on their annual utility bills" (DOE HOM-4). This rationale can be applied to existing homes where smart investment choices for retrofit can change the way the home operates on a more efficient level as heating and cooling together can make up at least half of a total utility bill (DOE MNG-4). Annette Conti the Executive Director of the Historic Chicago Bungalow Association points out that "older homes can appear to be a burden if you're faced with the increasing costs of energy consumption, [but] if you improve the energy efficiency of the home, you improve the long-term affordability."[71]

[69]"Energy Savers."
[70] "Building America Best Practices Series: Volume 4 - Builders and Buyers Handbook for Improving New Home Efficiency, Comfort, and Durability in the Mixed-Humid Climate," U.S. Department of Energy, September ,2005:HOM-4, NREL/TP-550-38448.
[71]Clare Martin, "6 Innovative Approaches to Historic Preservation," accessed January 27, 2013, http://www.oldhouseonline.com/6-innovative-approaches-to-historic-preservation/.

Table I - Operating Cost Estimates

	Annual Costs					Monthly Costs	
HVAC System	Heating	Cooling	Water Heating	Domesti c Energy	Total Operating	Htg., Clg.,& DHW	Total Operating
GeoExchange System Dual Fuel Back-Up	$978	$189	$243	$537	$1,947	$118	$162
Oil-Fired Furnace & Elec AC	$1,162	$236	$207	$572	$2,142	$131	$179
Gas-Fired Furnace & Elec AC	$1,025	$247	$169	$572	$2,013	$120	$168
Electric Resistance	$2,983	$230	$626	$537	$4,376	$320	$365
Elite© simulations provided by Northeast Utilities. Domestic energy includes energy use for lighting, appliances, cooking, and receptacle loads.							

Figure 26

The average usage costs of GHP for a typical 2,000 square foot home in the Northeast can be as low as one dollar a day with an annual projected heating cost of $978 if utilizing a backup system (Figure 26).[72]

From this table it is evident that overall utilization costs for a GHP (Geo-Exchange system) is less across the board compared to traditional oil, gas, and electric heating and cooling systems. The EIAs Residential Energy Consumer Survey found that because of the higher demand for heating in New Jersey compared to California, the average energy usage costs was $3,065; more than double the $1,423 cost in California.[73] Figure 3 graphically depicts this imbalance of energy costs throughout the country for homeowners utilizing conventional energy systems. From the graph, in 2009 the national average was equivalent to $2,024 per household while every state assessed in the Northeast fell clearly above that average.

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[72] "Geothermal Case Studies," Geo-Exchange Organization, accessed April 17, 2012, http://www.geoexchange.org/index.php?option=com_phocadownload&view=category&id=7:residential-case-studies&Itemid=291.

[73] "Independent Statistics and Analysis RECS Data Show Decreased Energy Consumption per Household RECS 2009," U.S. Energy Information Administration (EIA), Released June 6, 2012.

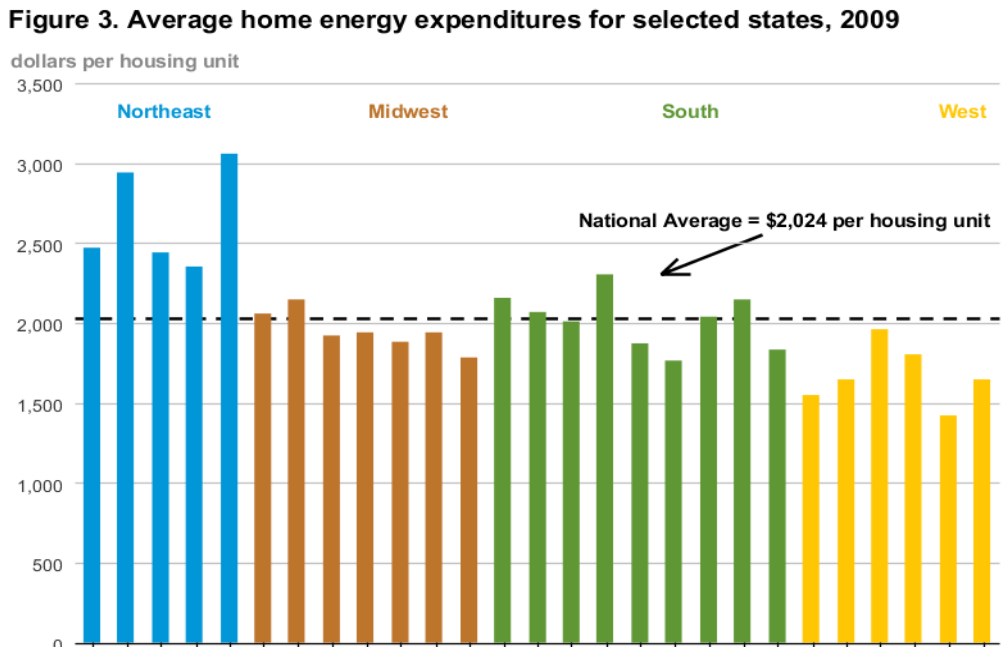
74 

Figure 27

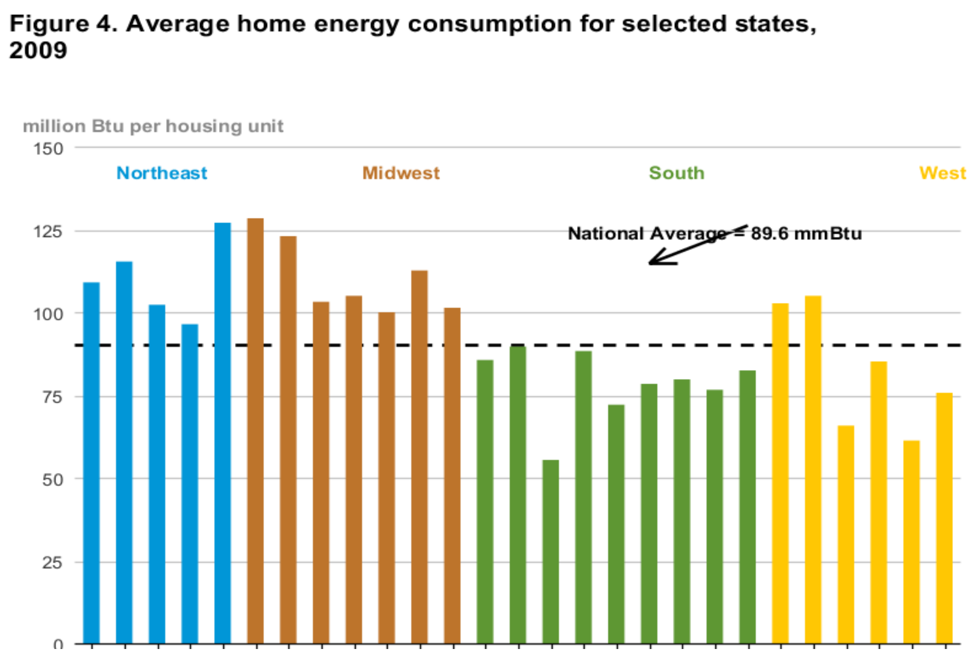


Figure 28

[74] "RECS Data Show Decreased Energy Consumption Per Household," Energy Information Administration, Fig.3-4.

Figure 27 shows the correlation between energy consumption and energy expenditures in figure 28. Again, the Northeast was over the national energy consumption average resulting in their higher energy costs compared to the rest of the United States.

Using statistics from the Census Bureau and the Energy Information Administration (EIA), the New York Times cite: "nationwide, the average household using oil spent $2,298 on heat last year (2011), compared with $724 spent by gas users and $957 spent by electricity users."[75] GHP, as discussed earlier and evidenced in Figure 20, uses three to four times less electricity to operate, therefore falls below these averages (Galloway, 94; Smith, 50). The EIA also predicted that for 2012, "heating oil users are expected to spend 3.7 percent more than last year, while natural gas customers are expected to spend 7.3 percent less and electricity users will spend 2.4 percent less" (Cardwell and Krauss, 2). The graph depicted in Figure 29 below shows the winter heating cost by conventional fuel for Northeastern homes from 2003 to 2012.

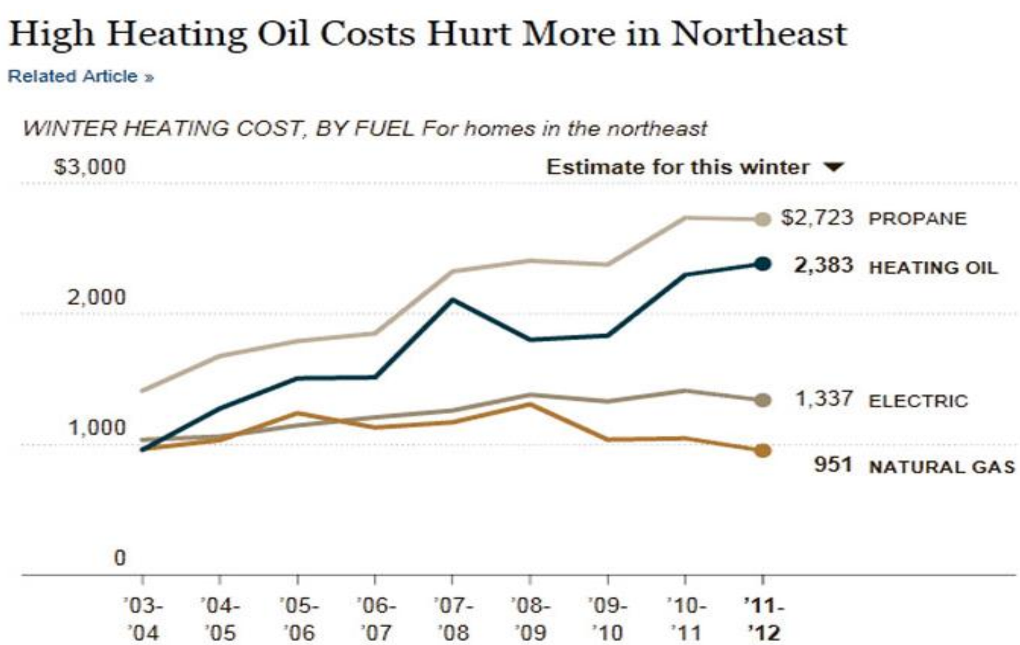


Figure 29

[75]Cardwell and Krauss, "Heating Oil Costs."

Electric appears to be one of the least expensive estimated sources, however knowing that GHP utilizes a fraction of that, it is a more viable system for an ECRH home owner employing a gas, oil or electric boiler system.

Lorraine Kreahling, a geothermal homeowner and writer for the *New York Times* noted that in her case the monthly electric bill did go up slightly because of the added use of the GHP system however her monthly fuel bill was "eliminated." She also noted a large decrease in the summer months where the cooling operation of GHP reduced her bill by half. In the same article, Gordon Bloomquist, a retired senior scientist at Washington State University assesses the regional disparity and cost savings by "whether you are competing with natural gas or propane or electric resistance…If electricity costs 10 cents a kilowatt, a heat pump will cost you 2.5 cents for the same amount of electric heat" (Kreahling). The Northeast is in great competition with conventional sources such as coal, oil, gas, and electricity as these have been the predominant energy sources for the region. Figure 30 compares GHP to conventional heating sources.

[76]

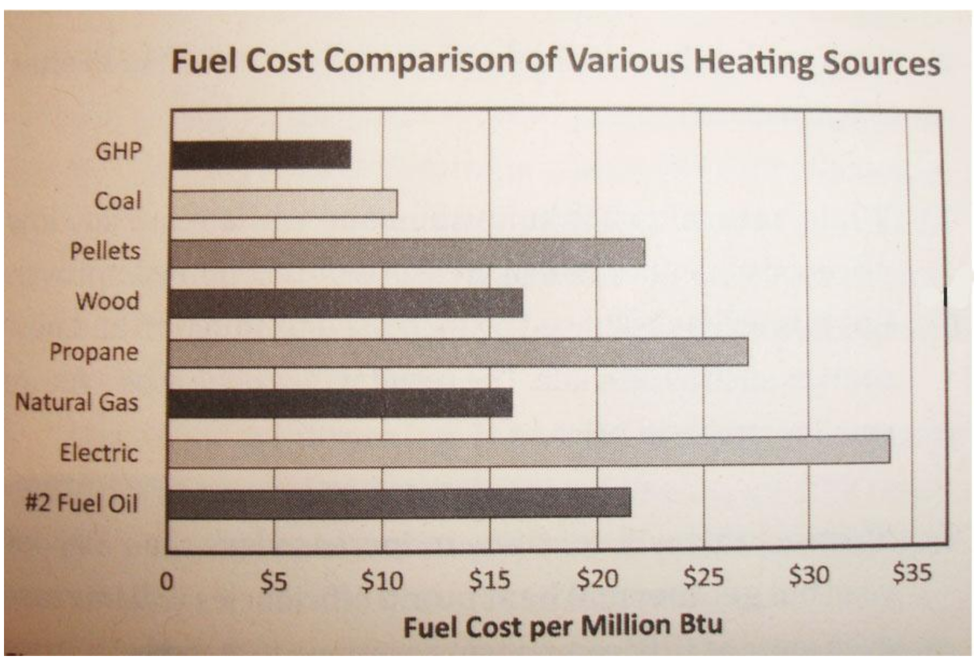


Figure 30

[76]Lloyd, "The Smart Guide to Geothermal," 23.

From the graph, GHP has the lowest cost compared to all other heat sources while electricity carries the highest cost. A reason for this is the fact that most utility electricity is generated from coal or distant fossil fuel power plants. There are additional costs incurred to produce and transfer that energy to consumable electricity, particularly if the residence is located further from the source. Additionally, the costs are highest for each conventional source when used during their seasonal peak periods. Electricity is predominant during the summer months to operate air conditioning units while oil and gas take over in the winter for heating; overall the homeowner is forced to manage at least two to three different sources all during their most expensive periods in the year.

Oil is a constant source of debate where there is no doubt of the international dependence on it, particularly in the commercial and industrial sectors. Because of the heightened awareness of the imbalanced supply and demand for oil, more social efforts have been popularized to reduce consumption and look to alternative resources. Donal Blaise Lloyd notes "from 2005 to 2008, shipments of GHPs in the United States doubled (121,243 units in 2008), in great part due to the surge in oil prices."[77] The constant fluctuation in oil prices is not new and when there is a rise there is typically a corresponding drop depending on the season and when the controls are determined. However there are some predictions that potential tapping of United States oil reserves will create the surplus that we currently demand and will therefore reduce oil costs and therefore reduce the rising desire for alternative energy. The fault in that argument is that the reserves will still be a limited finite supply, so while it may seem like a surplus it will in fact be limited and non-renewable, more likely to cause rationing and gouging prices. The statistical trends from the EIA evidence the rationale of movement away from nonrenewable energy, see Tables 2 and 3.

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[77]Lloyd, "The Smart Guide to Geothermal," 26.

[78]

(Thousand Megawatthours)

Period	Coal	Petroleum Liquids	Petroleum Coke	Natural Gas
Annual Totals				
2002	1,933,130	78,701	15,867	691,006
2003	1,973,737	102,734	16,672	649,908
2004	1,978,301	100,391	20,754	710,100
2005	2,012,873	99,840	22,385	760,960
2006	1,990,511	44,460	19,706	816,441
2007	2,016,456	49,505	16,234	896,590
2008	1,985,801	31,917	14,325	882,981
2009	1,755,904	25,972	12,964	920,979
2010	1,847,290	23,337	13,724	987,697
2011	1,733,430	16,086	14,096	1,013,689

Table 2 -Net Generation by Energy Source: Total (All Sectors), 2002-November 2012

(Thousand Megawatthours)

Period	Wind	Solar Thermal and Photovoltaic	Wood and Wood-Derived Fuels	Geothermal	Other Biomass	Total (Other Renewable Sources)
Annual Totals						
2002	10,354	555	38,665	14,491	15,044	79,109
2003	11,187	534	37,529	14,424	15,812	79,487
2004	14,144	575	38,117	14,811	15,421	83,067
2005	17,811	550	38,856	14,692	15,420	87,329
2006	26,589	508	38,762	14,568	16,099	96,525
2007	34,450	612	39,014	14,637	16,525	105,238
2008	55,363	864	37,300	14,840	17,734	126,101
2009	73,886	891	36,050	15,009	18,443	144,279
2010	94,652	1,212	37,172	15,219	18,917	167,173
2011	120,177	1,818	37,449	15,316	19,222	193,981

Table 3 - Net Generation by Other Renewable Sources: Total (All Sectors), 2002-November 2012

[78] "Electric Power Monthly with Data for November 2012 - January 2013," Department of Energy, 22-23, accessed January 27, 2013,www.eia.gov.

Table 2 shows the decline of conventional energy sources over the past ten years with particular significant change in the amount of coal and petroleum based liquid energy generated. Natural gas however has increased dramatically and has been on the rise due to the shift to more natural sources. Table 3 corresponds to the generation of 'other' renewable sources with notable rise in wind, solar and geothermal, while wood is on the decline as it is not a readily renewed source. Wind and Solar show the greatest increase because of their use in commercial and industrial scale markets. Overall the total trend for renewable source generation is on a greater increase while conventional sources continue to decline.

Evidenced from this statistical trend data, over time GHP will continue have an increasing production advantage over the declining conventional sources. It will also take more improvements in special high efficiency systems to convert oil and gas boilers to the level of one GHP. As seen with Direct Exchange GHP, the system continues to make advances and according to Lloyd, "[GHPs] have not yet peaked and are still increasing…in time, newer GHP components will be able to do the same work with less electricity" (Lloyd, 25). Figure 31 depicts Lloyds projected GHP advantage in the future, showing oil continuing to rise in price, natural gas plateaus with a gradual increase, while GHPs maintain a steady downward cost slope.

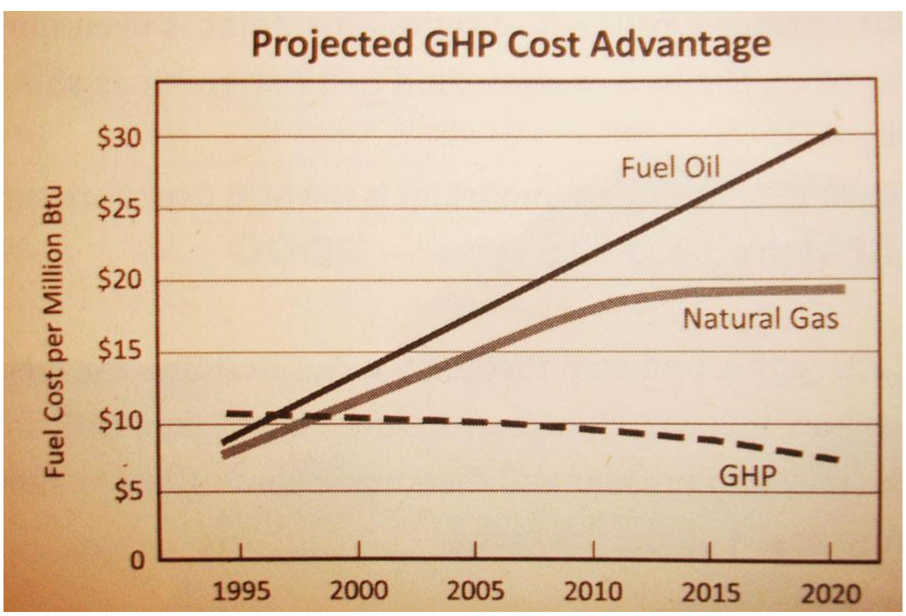

Figure 31

2.5 GHP Efficiency Analysis

Efficiency is typically understood based off its literal definition of the degree to which a desired result is achieved without wasted energy or effort. For the technical aspect of measuring thermal heat efficiency, the equation is:

COP (Coefficient of Performance) = EER (Energy Efficiency Ratio: Output/Input)

The COP is used to measure the resultant heat output while the EER reflects the amount of output capacity (Btu/Hour) divided by the power input (Watts), this number can range from 9-31 and reflect a percentage of energy performance typically associated with cooling.[79] What is unique about geothermal, is that the EER is typically over 100 % because 'free' energy is gained from the ground itself and is factored into the output capacity. For example: "1 unit of energy from electricity from the power grid with 4 units of free energy (COP 4) from the ground will achieve 5 units total, (1+4/1) so that equates to 500%" (See Figure 32). [80]

Figure 32

This excess in efficiency is precisely why usage and long term costs are so much lower and create a faster investment return over conventional systems. To ensure proper efficiency for any system, it is important to assess the proper size and capacity based off the space required. As discussed earlier, one of the downfalls of many older homes,

[79]Lloyd, "The Smart Guide to Geothermal," 124.
[80]"Renewable Technology," Energy Environmental, EnergyHomes.org, accessed February 17, 2013, http://www.energyhomes.org/renewable%20technology/geoefficiency.html.

particularly ECRHs, is the overproducing boiler systems that created wasted excess energy. Thankfully with a GHP system, that energy is recycled and pumped back into the earth and redistributed to complete the next cycle. An example of the difference between a conventional boiler and a GHP would be "if the electricity comes from a conventional power station operating at about 35% efficiency and the heat pump has a COP of 3.5, then the heat pump will be 1.4 times more energy-efficient overall than a gas-fired boiler."[81]GHPs also manage their work load throughout the year in a continuous operating cycle when in use thereby reducing the off/on demand inconsistencies often found with standard gas fired heaters and boilers.[82]

The EIA's Electric Power Monthly (EPM) report provides government officials with a standing on the energy and electric power industries. Figures 33 - 35 show the increase in GHP shipments by model types as well as the average heating and cooling efficiencies for each one.[83]

(Number of Units)

Year	Model Type				
	ARI-320	ARI-325/330	ARI-870	Other Non-ARI Rated	Total
2000	7,808	26,219	-	1,554	35,581
2001	NA	NA	NA	NA	NA
2002	6,445	26,802	-	3,892	37,139
2003	10,306	25,211	-	922	36,439
2004	9,130	31,855	-	2,821	43,806
2005	9,411	34,861	-	3,558	47,830
2006	10,968	47,440	-	5,274	63,682
2007	8,112	66,863	809	10,612	86,396
2008	23,204	91,402	783	5,854	121,243
2009	22,009	87,717	759	4,957	115,442

Figure 33 - Geothermal Heat Pump Shipment by Model Type 2000-2009

[81]"Geothermal Heat Pumps," Earthscan.
[82] Woodroof, "Drill, Baby, Drill!"
[83] "Electric Power Monthly," Energy Information Administration, 4.

(Average COP)

Year	Model Type			
	ARI-320	ARI-325/330	ARI-870	Other Non-ARI Rated
2008	4.4	4.0	4.2	3.6
2009	3.9	4.1	4.3	3.8

COP = Coefficient of Performance.

Figure 34 – Average Heating Efficiency for Geothermal Heat Pump Shipments 2008-2009

(Average EER)

Year	Model Type			
	ARI-320	ARI-325/330	ARI-870	Other Non-ARI Rated
2008	13.1	19.5	17.5	13.5
2009	14.6	20.4	18.2	14.3

EER = Energy Efficiency Ratio.

Figure 35 – Average Cooling Efficiency for Geothermal Heat Pump Shipments 2008-2009

Figure 33 summarizes the rise in GHPs from 2000-2009 with the most popular models being the ARI-325 (ground water –source heat pumps) and the ARI-330 (ground source closed-loop heat pumps), both predominantly used for residential installations. This increase of 61,498 units is telling of the popularity and the growth of the industry.

According to Figure 35, the average heating COPs is 4 while the cooling efficiency averages an EER of 17 in Figure 34. These are high efficiency figures as "most geothermal heat pump systems have COPs of 3-4.5…where a fossil fuel furnace may be 78-90 percent efficient," the equivalency of a 0.8 COP rating.[84] Most conventional fossil fuel systems are measured off percentage of efficiency whereas cooling is measured based off EER. Ultimately they all measure the same information of energy input/output but are expressed in various ways to appeal to the observed measurement standard (ex: metric vs. feet). Figure 36 below compares the heating and cooling efficiencies of geothermal to conventional systems.

[84]"Renewable Technology," Agency, E.P., *Space Conditioning: The Next Frontier*. 1993. via Energy Environmental, EnergyHomes.org, accessed February 17, 2013.

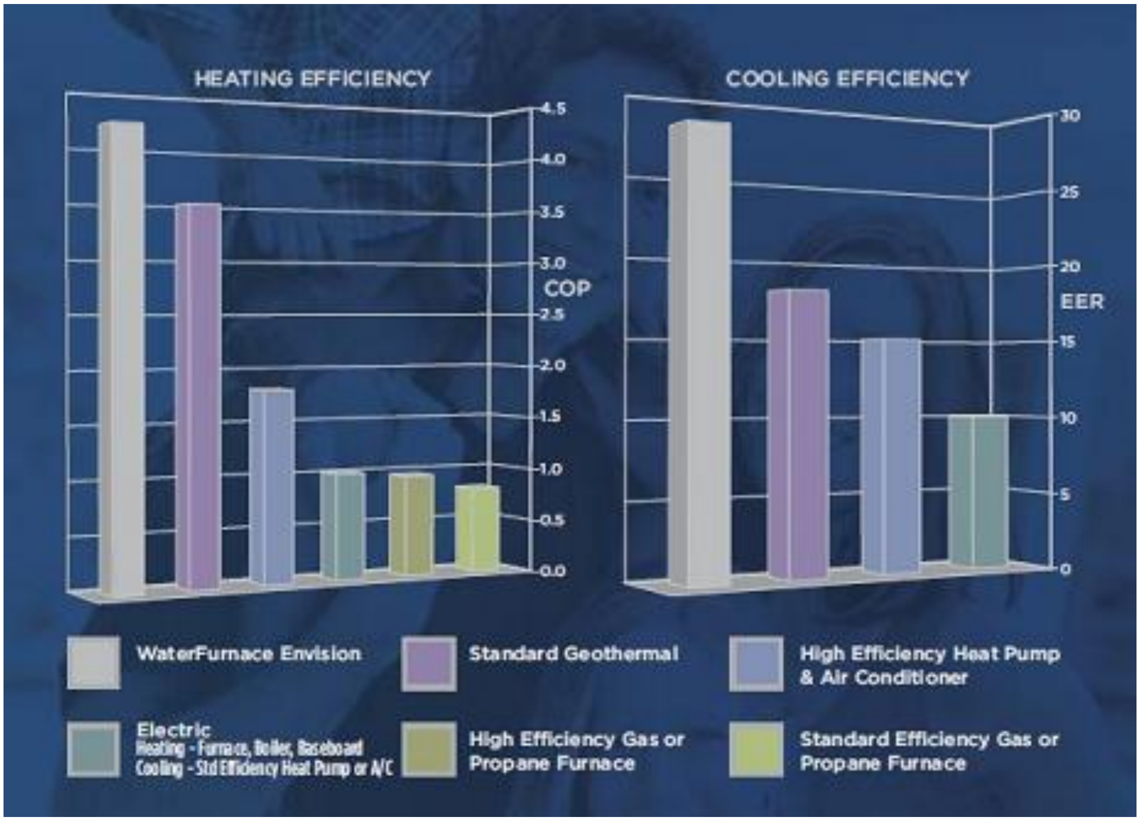

Figure 36

From this graphic the heating efficiency of GHPs (*WaterFurnace* and Standard Geothermal) is approximately 2.5 COP or 250% higher than conventional gas and propane systems that measure an efficiency of 0.75 COP or 75% (*ibid).* For cooling the same results are present with the GHP systems trumping the conventional electric systems by approximately 18 EER. Overall, "high-efficiency geothermal systems are on average 48 percent more efficient than gas furnaces, 75 percent more efficient than oil furnaces, and 43 percent more efficient when in the cooling mode."[85]

To make the GHP system even more efficient and a nearly ideal "Zero Energy" house, is if the home is also supplied with a renewable electricity source. Unfortunately that option is often dependent upon the established infrastructure and options provided within the area. An ECRH located in a dense city without wind farms or solar collectors to source alternative electricity may not have another feasible option without additional

[85] "Renewable Technology," Energy Environmental, http://www.energyhomes.org/renewable%20technology/geoefficiency.html.

investment funds. The only other option would be to invest in a separate modular/residential alternative electricity source for on premise generation which for a historic ECRH would need deeper examination so as to not detriment the building preservation.

The history of ECRHs and their current inefficiencies highlight the need for drastic upgrades to their thermal envelopes and space heating and cooling systems. To reiterate the heating dilemma facing historic ECRHs, Figure 22 provided by the National Park Service (NPS) compares energy consumption for homes built before 1950 (most ECRHs) to buildings built after 2000.[86]

[87]

Residential Energy Use Intensity by Age

Year Built	KBtu/sq ft/yr
Prior to 1950	74.5
1950 to 1969	66.0
1970 to 1979	59.4
1980 to 1989	51.9
1990 to 1999	48.2
2000 to 2005	44.7

Source: Residential Energy Consumption Survey, 2005

Figure 37

The energy use prior to 1950 is “30 to 40 percent” less efficient than homes built after 2000, which is primarily due to the inefficient space heating systems and poor insulation. This research has proven GHP to be less costly and consuming than standard heating systems and provides an abundance of nearly “free” heat return. Despite the initial cost to install, GHP “delivers more energy per unit consumed” and is thereby more efficient and saves money for the homeowner.[88] The GEO confirms with the Environmental Protection Agency (EPA) that GHPs are an average “48% more efficient than the best gas furnaces…and over 75% more efficient than oil furnaces.”[89] Knowing the superior efficiency of GHP, how does that translate into money savings for the homeowner?

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[86]Hensley and Aguilar, “Improving Energy Efficiency in Historic Buildings.”
[87]“Residential Energy Consumption Survey 2005.”
[86]“Energy Savers.”
[89]"Geothermal Facts.”

2.6 GHP Benefit Analysis: Investment Return and Tax Incentives:

Based off the EPA and DOE percentages of GHP efficiency, the National Association of Home Builders (NAHB) reports a "savings between $358 and $1,475 annually" for homeowners utilizing GHP systems for heating and cooling.[90] NAHB further confirms that most consumers "justify the initial investment [approximately $11,000] with the savings they expect to realize on their heating and cooling bills over time." For the average household on the East Coast that spends $2,298 on space heating with oil, that is a 64% cash savings per year, therefore in efficiency return alone, a GHP overhead cost between $11,000 and $20,000 will achieve return after 7 – 13 years. Considering that the systems are under warranty for up to 50 years, an average of 10 years is a reasonable amount of time. Furthermore, available financing through energy-efficient mortgages allows GHP overhead cost inclusion to the homes total equity. This would average approximately 0.8% or $88 extra dollars a month for an $11,000 GHP, but would be offset by the reduced utility bill.

Federal and state governments are making strides to support homeowners in their quest for energy efficiency and home preservation. The Secretary of Energy, Steven Chu announced in 2010, a 20 million dollar grant towards the research and development of "non-conventional geothermal energy technologies" (Kumar, 1). Effective in 2009, as part of the *American Recovery and Reinvestment Tax Act of 2009 (ARRTA)*, The Federal Tax Incentive Program for Renewables and Efficiency provided that:

> A taxpayer may claim a credit of 30% of qualified expenditures for a system that serves a dwelling unit located in the United States that is owned and used as a residence by the taxpayer. Expenditures with respect to the equipment are treated as made when the installation is completed. Expenditures include labor costs for on-site

[90] "Geothermal Heat Pumps," NAHB Research Center, accessed April 15,2012 ,http://www.toolbase.org/TechInventory/techDetails.aspx?ContentDetailID=754.

> preparation, assembly or original system installation, and for piping or wiring to interconnect a system to the home. If the federal tax credit exceeds tax liability, the excess amount may be carried forward to the succeeding taxable year. The maximum allowable credit, equipment requirements and other details vary by technology.[91]

According to this act, the Federal government will grant homeowners a 30 percent return on the total cost of a GHP system with no maximum incentive for GHPs in service after December 31, 2008.[92] In effect, the ECRH homeowner with a GHP retrofit will achieve total investment return in five to nine years, combining the efficiency return over time with this 30 percent rebate. Section 1603 of the ARRTA also contains a provision for cash grants up front in lieu of end of year tax credits. In fact, "as of February 25, 2011, a total of 7,180 alternative energy projects were funded through the §1603 program, totaling $6.4 Billion in Treasury funding."[93]This funding primarily covers solar, geothermal, biomass, and wind, with the bulk of projects applied to the industrial and commercial sectors. The residential sector receives a smaller share due in part to the much smaller demand, however the grants and credits are open to homeowners in almost every state. Table 4 below from the *Database of State Incentives for Renewables and Efficiency (DSIRE)* outlines the Federal, State, Local, Utility, and Private incentives available to homeowners in each state (due to the length of the table for all 50 states and territories, select states are included that correspond to warm versus cold climate regions and areas with greater populations of historic row houses).

[91] "Federal: Incentives/Policies for Renewables & Efficiency," Department of Energy, accessed April 15,2012, http://www.dsireusa.org/incentives/incentive.cfm.
[92]"Tax Incentives," Department of Energy, accessed April 15th, 2012 "http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F&re=1&ee=1.
[93]Goulding et al., "Fast Growing Success of Alternative Energy Cash Grant Program."

Financial Incentives for Renewable Energy [94]

State	Personal Tax	Corp. Tax	Sales Tax	Prop. Tax	Rebates	Grants	Loans	Industry Support	Bonds	Performance -Based Incentive
Federal	3-F	4-F				4-F	6-F			
Alaska				1-S		1-S	2-S			1-U
Arizona	4-S	2-S	1-S	2-S	9-U 1-L		1-U	1-S		
California			1-S	1-S	8-S 46-U 3-L		3-S 1-U 6-L	1-S		1-S 2-U 1-L
Colorado			2-S 1-L	3-S	20-U 2-L	1-L	2-S 1-U 2-L			2-U
Connecticut			3-S	1-S	2-S 2-U	3-S	5-S 1-U	2-S		4-U
Delaware					2-S 3-U		1-S			2-S
Florida		1-S	1-S		21-U 1-L		1-S 6-U 3-L	1-L		2-U
Hawaii	1-S	1-S		1-L	1-S 1-U		3-S 2-U 1-L			1-S
Maine					1-S		2-S 1-L			1-S
Maryland	2-S	2-S	4-S	4-S 9-L	5-S 5-U		4-S			1-S
Massachusetts	1-S	2-S	1-S	1-S	5-S 10-U 1-L	6-S	1-S 1-U	2-S		1-S
Michigan				2-S	7-U	1-S 1-L	4-S 2-L 2-P	4-S		1-U
Minnesota			2-S	1-S	76-U	1-S 2-U	8-S 2-U			1-S
Montana	3-S	1-S		3-S	4-U	1-U	1-S	2-S		
Nebraska	1-S	1-S	1-S	1-S	3-U		1-S			
Nevada			1-S	3-S	2-S 3-U		2-S 1-U			1-S
New Hampshire				1-S	3-S 7-U	2-S	3-S			
New Jersey			1-S	2-S	5-S	2-S	2-S	3-S		2-S
New York	2-S	1-S	3-S 1-L	3-S 1-L	8-S 6-U		3-S	1-S		2-S 1-U
North Carolina	1-S	1-S		2-S	11-U 1-L		2-S 3-U 1-L	1-S		2-U 1-P
North Dakota	1-S	1-S	3-S	2-S	1-U		2-U			
Oregon	3-S	3-S		1-S	6-S 16-U	3-S 1-P	3-S 8-U	1-S		1-S 1-U
Pennsylvania				1-S	1-S 8-U	6-S 2-L	6-S 1-U 5-L	3-S		1-S
Rhode Island		1-S	1-S	2-S		2-S				1-S
Vermont		1-S	1-S	2-S	1-S		1-S			1-S 2-U
Virginia	1-S			1-S			2-S 1-U	3-S		2-U
Washington			1-S		13-U	1-P	9-U	1-S		1-S 3-U
Wisconsin	1-S	1-S	1-S	1-S	3-S 7-U	1-S	1-S 2-L			2-U
Wyoming					7-U		1-S			
District of Columbia				1-S	1-S		1S			1-S
Totals(all50st.)	45	43	46	77	549	55	201	39	3	74

F = Federal S = State/Territory L = Local U = Utility P = Private

Table 4

[94] "Federal: Incentives/Policies for Renewables & Efficiency."

The highlighted states are those in the Northeast with the highest ECRH populations and highest energy costs in the country. Majority of the incentives for all 50 states come in the form of rebates with various types dependent on the systems employed, the efficiency outputs, and the cost incurred. Ironically, utility companies also offer incentives to alternative renewable energy systems due to the lowered demand and burden placed on their grid systems, especially during peak periods.

Furthermore, the U. S. Environmental Protection Agency (EPA) considers "geothermal heat pumps the most energy efficient, environmentally clean and cost-effective HVAC system available" and recognizes its growing residential potential, especially in New England as highlighted in the EPA "New England, Energy and Global Climate Change" education initiatives.[95][96] GHP advances and cost improvements in the near future are projected to grow "almost exponentially over the next 40 years," according to Charles Goulding, Joseph Moat and Spencer Marr, tax attorney's and analysts specializing in building energy efficiency incentives. Validating this prediction, the National Renewable Energy Laboratory (NREL) provides the following geothermal assessment: "7,385 MWt of geothermal capacity was available in the U.S. in 2006…[the NREL] expect that number to grow to 18,400 MWt in 2015, 66,400 MWt in 2025 and over 1,000,000 MWt by2050" (*ibid*). Many of the incentives outlined in by DSIRE as part of the ARRTA expire in 2013 with some extensions available until 2016. Knowing these deadlines, and the expected doubling in geothermal capacity within that time, it is crucial that the government reevaluate and extend their incentive programs for homeowners to realize this growing potential. Likewise, advanced geothermal systems such as Direct Exchange (DX) offer more flexibility and cost savings for the homeowners but may not be covered in the current incentive stipulations due to lack of research and evaluation established in 2009.

Ultimately, the increased efficiency, limited usage costs, sustainability, and government rebate incentives for the GHP will increase the value of a retrofitted ECRH.

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[95]Goulding et al, "The Energy Tax Aspects of Geothermal Heat Pumps."
[96] "Energy and Global Climate Change in New England, Geothermal Energy," Environmental Protection Agency, http://www.epa.gov/region1/eco/energy/re_geothermal.html.

The National Association of Realtors Appraisal Journal estimates that a home's value "increases by $10 to $25 for every $1 reduction in utility bills."[97] Knowing that the NAHBs GHPs' assessed annual savings is approximately $1,475, a home's value will increase by approximately $36,875. Compounded over the years with the increased value of alternative energy to expensive fossil and natural fuels, this number is likely to increase even further. For a historic ECRH, this increase in home value will subsequently raise the value of its preservation, earning it recognition and security as a sustainable property.

[97]"Geothermal Facts."

2.7 Published Case Studies

2.7.1 European Union Energy Efficient Buildings Initiative

In 2009 the European Union drafted new measures that would require by law, buildings be brought up to certain sustainable measures by the year 2020. The directive states, "The European Union has signed up to binding, EU-wide targets pledging to meet 20% of its energy needs from renewable energy sources such as biomass, geothermal, hydro, wind and solar by 2020".[98] These target improvements include both new and historic buildings so that the EU can start to develop their own independent energy sources. By combining energy-saving measures with renewable energy sources, the total consumption of conventional energy in buildings can be reduced to zero. Buildings can even become net producers of clean energy: they can be fitted with solar water and space heating and cooling systems, building-integrated photovoltaic and rooftop photovoltaic systems, and biomass-fueled energy systems, as well as small-scale ground coupled GHPs.

The EU plans to stand steadfastly on this topic, stating: "Member States should ensure that certification schemes or equivalent qualification schemes are available by 31 December 2012 for installers of small-scale renewable energy systems in buildings, like biomass boilers and stoves, solar photovoltaic and solar thermal systems, shallow geothermal systems and heat pumps."[99] Obviously, if the entire European Union is putting out a directive to its member countries to incorporate these energy systems, with emphasis on GHPs, they must have great validity and trust that these systems are not only the best move toward the future for of the Union but best for consumers as well. Knowing that, incorporating GHPs into our own historic row houses is strongly valid and means the United States is behind its counterparts in Europe.

[98]"Directive of the European Parliament and of the Council on Energy Efficiency and Repealing Directives," European Commission, Brussels: 2011, 2011/0172 (COD).

[99]"Renewable Energy In Buildings," Intelligent Energy Europe (IEE), Project Report 9, April 2009, 2, accessed April 23, 2012, IEE-Library.eu.

2.7.2 "Greenspur Project:" Cunningham and Quill Architects, Washington D.C.[100]

The "Greenspur Project," by Architects Ralph Cunningham and Lee Quill is a complete historic preservation renovation and utility retrofit of a Federal Row House in the Capital Quarter of Washington D.C. The home was built in 1852, 160 years old at the time of renovation, and maintained the extremely old and rare wood façade that was typically replaced with brick in the early 1800s. The home was on the docket for demolition until this firm saved the building by incorporating new sustainable elements and returning the row house to its original glory.

Due to the extreme dilapidation of the interior, Cunningham and Quill were unable to retain the original historic details. Images 7 and 8 illustrate the poor condition of the home prior to restoration.

Image 7

Image 8

The images evidence the extreme challenge the architects had in order to preserve the structural integrity of the home while giving it new life by stripping away the updates of the siding and awnings. The windows were shoddy double hung storm windows that the architects replaced with an authentic 6-6 configuration. The "Owens Corning Energy

[100] "Capitol Hill Press Release," Greenspur, accessed April 5, 2012, http://greenspur.net/learningcenter/learningcenter.htm.

Complete" system was installed that yields "twice the performance of traditional building code insulation" by providing a tighter efficiency envelope.[101] One of the greatest improvements to the home is the installation of Geothermal heating and cooling zoned throughout the home. The images show small lot space of the home, lending support to the fact that GHP can be incorporated in compact areas by utilizing a vertical configuration. The GHP system was installed in the front of the property utilizing a compact drill that laid a vertical loop system similar to the process described in the installation discussion earlier. The "Greenspur" location contains soil that is a mix of rock, sand, and clay that was beneficial as it keeps the wells firmly intact while providing the necessary temperature properties.[45]

Ultimately the designers turned this 900 sq. ft. historic ECRH into a 2100 sq ft. marvel. Images 9 and 10 illustrate the corresponding "after" pictures of the home, post restoration.

Image 9

Image 10

[101]"Capitol Hill Press Release."

The firm made a point to leave the front façade of the home as close to the original Federal style as possible given the state of the house. The back portion was modernized and another level was added, increasing the overall size of the home and residential value. Figure 38 is the final layout and floor plans the Architects developed to maximize this homes new found potential.

Figure 38

The new designs feature an "open floor plan" with an expansion added to the back of the home to bring in more natural light so that it may allow for passive design aesthetics that were not in the original build. The U-shaped stair layout was replaced for a straight run to alleviate the clutter that was forming in the center of the home, which in turn makes the home appear more authentic. In the end, appraisal results from the efficiency improvements made on this home jumped it from the condemned list to the "top 1% of efficient homes in the country" and Washington D.C.s first "Carbon Neutral" home![102]

[102]"Capitol Hill Press Release."

2.7.3 GEO, "Energy Craft Home": Hartford, Connecticut[103]

This case study focused on the "Palmer Residence," a historic colonial home in East Hampton, CT that is a prime example of home efficiency improvement as a result of a GHP retrofit. The two-story, 3,537 square foot house incorporated improved windows yielding a U-value of 0.36; sprayed foam and blown cellulose insulation resulting in R-values of 20 and 50; and air-sealing measures to supplement the GHP retrofit for optimal heating efficiency. The house was fitted with a 4.2 ton "Water Furnace, Geo-Exchange heat pump, a closed loop ground heat exchanger, two vertical 250-foot wells, and 1,000 feet of polyethylene tubing" (GEO, 2).

The total GHP system cost to the Palmers was "$19,283" and included the equipment, ductwork, and ground-loop installment. Before deciding on the GHP retrofit, the owners were quoted "$16,200" for an oil driven furnace and an electric central air conditioning system (*ibid*). Ultimately, they made the best decision with the GHP where they received a tax rebate of "$713 per ton for a total of $2,971," and earned back "$1 per square foot of conditioned space for their supplemental improvements, generating a total return of "$5,958" (*ibid*). In the end the owners net investment cost was "$13,325," well below the competition that would have yielded no rebates. After a successful retrofit, the family's average monthly heating and cooling costs were "$93.52" almost half of the average monthly heating costs in the northeast (Figure 16).

An assessment of this case study conducted by the Natural Resources of Canada in conjunction with RETSCREEN International found that "rebate programs can significantly influence the financial viability of a ground-source heat pump…residential systems that use relatively little energy will often lead to longer payback times for ground-source heat pump systems" as experienced by this family in Connecticut.[104] The Canadian analysis finds that homeowners are more willing to withstand longer payback periods if it results in comfort, environmental benefits, and short term savings that can be

[103] "Geothermal Case Studies: Energy Crafted Home, Hartford Connecticut," Geo-Exchange Organization," accessed April 17, 2012, http://www.geoexchange.org/index.php?option=com _phocadownload&view=category&id=7:residential-case-studies&Itemid=291.
[104] "RETSCREEN," Natural Resources Canada, accessed February 21, 2013. http://www.retscreen.net/ang/home.php

seen on a monthly basis. They agree that due to lack of homeowner and builder education, awareness of GHPs and the benefits are unknown and/or intimidating especially to mid/low-income home owners that need the long term savings the most.

2.7.4 "The Plant": Baltimore, MD[105]

"The Plant" was a project submitted to the Baltimore Bioneers Conference in 2008 for a greener way of building in Baltimore. The aim of the project was to produce a network of heating and power sources for a block of vacant homes. The GHP system was proposed in hopes of assisting a block of row houses in a lower class neighborhood to support their utility costs for heating homes from one centrally located area between all of the row houses. With this direction of construction, each home would not have to be separately adapted with a GHP system. This universal construction approach would provide each home with efficient heating to this lower class neighborhood. This model was aimed at restoring communities and filling in the gaps between the crumbling row houses that use to thrive with working class citizens but unfortunately are now disintegrating.

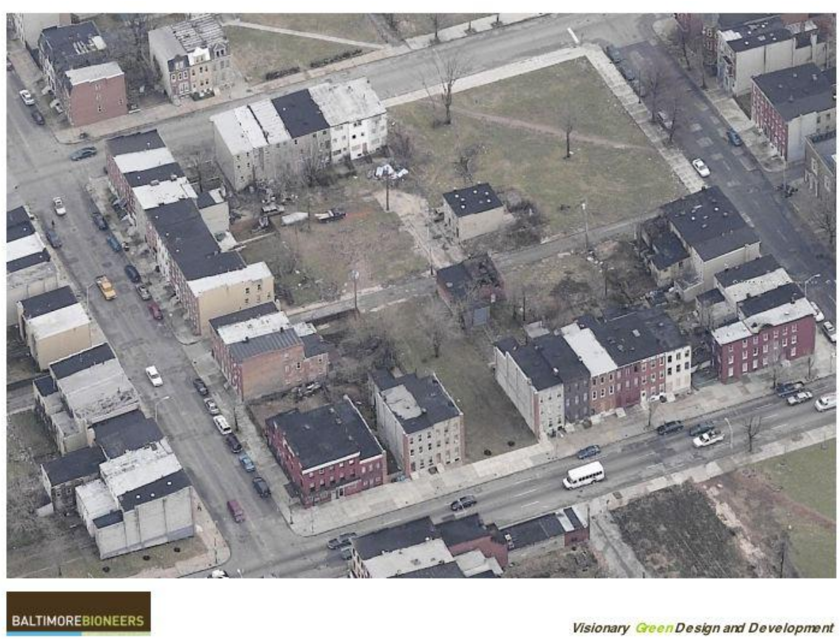
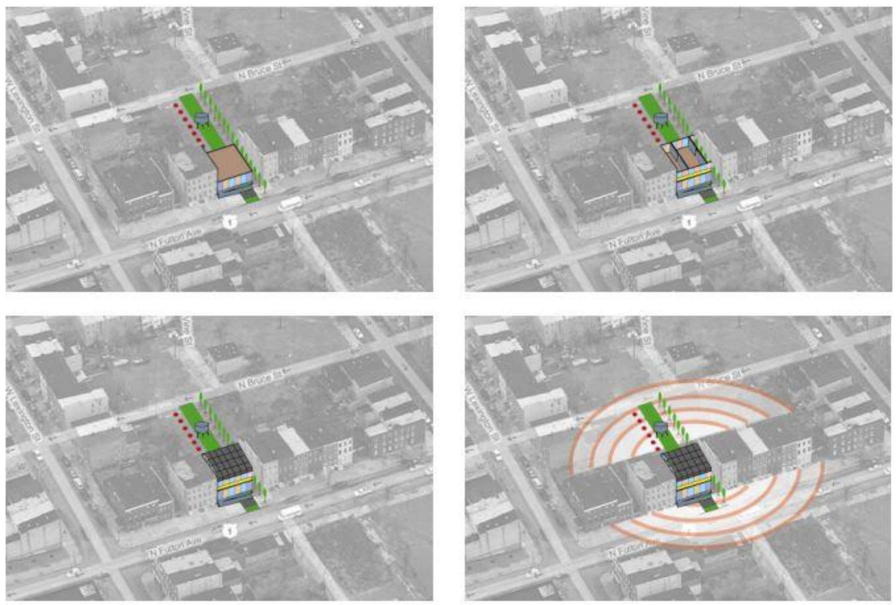


Image 11

[105] "Geothermal Case Studies: Baltimore Neighborhood Project" Baltimore Plant, accessed February 4th 2012, http://baltimoreplant.blogspot.com/.

Image 11 above, shows how Baltimore unfortunately looks today; row houses dot the street with empty vacant lots. Figure 39 below depicts that same area but with the proposed Geothermal wells and a new row house built in the vacant lot among the old. The bottom right image highlights the range at which one single GHP system could cover almost the entire block with efficient heating and cooling.



BALTIMOREBIONEERS

Figure 39

Visionary Green Design and Development

The bottom level of the new buildings would have been made up of local stores and community centers while the upper levels could be rented out. This would have ultimately increased the value of the area and potentially salvaged the entire neighborhood. Unfortunately for reasons unknown, this project was not implemented into action, but was a feasible concept that is utilized in Europe.

2.8 Research Limitations

The sources of information for this portion of the research came from numerous government agencies, geothermal organizations, preservation manuals, academic textbooks, and accredited popular social publications. Throughout the entire research, no substantiated negative information could be found regarding the importance and value of preserving historic homes, particularly ECRHs. Likewise, very little criticism to GHP as an efficient and viable heating and cooling source could be found. Of the challenges found, all related to the high overhead cost of GHP installation. This area of concern was addressed by comparing the costs of conventional systems and unveiling the various credits, rebates and incentives available to GHP homeowners to offset the high initial investment.

Limitations to access made identifying real home owner experiences difficult. Though the published case studies and the testimonies of GHP clients from the various geothermal organizations are important and very telling of actual experiences, further cost/savings information from regional utility companies would have provided more concrete figures. Further internal documents from architecture and engineering firms, and other alternative energy companies would have also provided more comparison data. Residential market value information, especially for a GHP retrofit (or any other alternative energy system retrofit) was severely limited to general online market summaries that lacked any added numerical value placed on these systems. Articles from nationally accredited real estate and appraiser publications provided some valuable insight but not enough figures and data to give a substantial assessment of home value change with utility upgrades.

The next chapters will discuss and go into detail on the direct applied research conducted in Washington D.C. during the peak winter months to validate or refute the information obtained from the literature review.

3 Applied Research Design

The following chapter contains first hand research conducted to qualify the published information obtained in the literature review. The purpose of the additional research is to verify whether GHP is in fact a viable solution to the space heating dilemma especially for historic East Coast Row Houses. The objective is to fulfill the research questions presented at the beginning of this document with solid qualitative and quantitative evidence. From the information obtained from the secondary research and literature review, it is my assertion that a geothermal retrofit on historic ECRHs will reduce utility costs by at least 40 percent, increase the market value of the home, be practical to enhance preservation while providing an investment return within 10 years. The methodology of how the research was conducted and the manner of data collection is discussed in the next section. The research design will outline the studies parameters followed by a summary of the results and conclusive summary of findings in Chapter 4.

3.1 Methodology

This portion of the research is a combination of quantitative and qualitative data collection aimed to provide substantiated analysis supplemented by real world application through field expert testimony and controlled computer modeling. The methods and standards used to conduct the qualitative field interviews and the 3-D computer analysis case study is detailed below.

<u>Qualitative Field Interviews:</u>

Interviews of regional (North East - Midatlantic) field experts and ECRH home owners contributed the first hand knowledge base and insight to compare with the published literature to ensure balance of information and opinion. Prior to conducting any personal communications with outside sources, approval from the *University of Hawaii Human Studies Program* was granted for exemption status to the Institutional Review Board government requirements (See Appendix B). Interviews were conducted in person and over the phone, with each participant offered an informational letter describing the nature of this study and what would be requested of them as participants in the research (See Appendix B). Interviews and observations were documented using field notes and voice recording (with granted consent) to ensure information was accurately captured and transcribed for proper citation. Site visit photographs were captured to document the systems and components referenced during the interviews. All participants were over the age of 18 and were briefed on their rights to confidentiality and discontinued participation at any time. For the participants requesting credit of their work or that of their company, proper citation is included where applicable in this research document.

The intended sample of participants was 50 certified professionals in the fields of architecture and engineering, government, real estate, preservation, and geothermal design/installation. Participants were identified based off published credentials and references from other professionals involved. The table below outlines the outcome of contact to response and successful participation for the interview portion of this research:

Table 5 - Field Professional Sample for Interview Research

FIELD PROFESSION	# CONTACTED	# DECLINE/NO RESPONSE	# ACCEPT
ARCHITECTURE/ ENGINEERING	12	7	5
GOVERNMENT: ENERGY CO	3	3	0
REAL ESTATE: APPRAISER	7	3	4
ACADEMIC: PRESERVATION	8	5	3
GEOTHERMAL: DESIGN/INSTALL	15	11	4
HOME OWNERS: ECRH, GHP, ALTN	6	2	4
TOTAL	51	31	20

Homeowners of ECRHs, GHP, or other alternative utility systems were difficult to identify and contact without disruption or disclosure of personal identifying information. Of the homeowners successfully contacted and interviewed, all were obtained through prior introduction via an Architect or GHP expert who had worked with the client on a previous project.

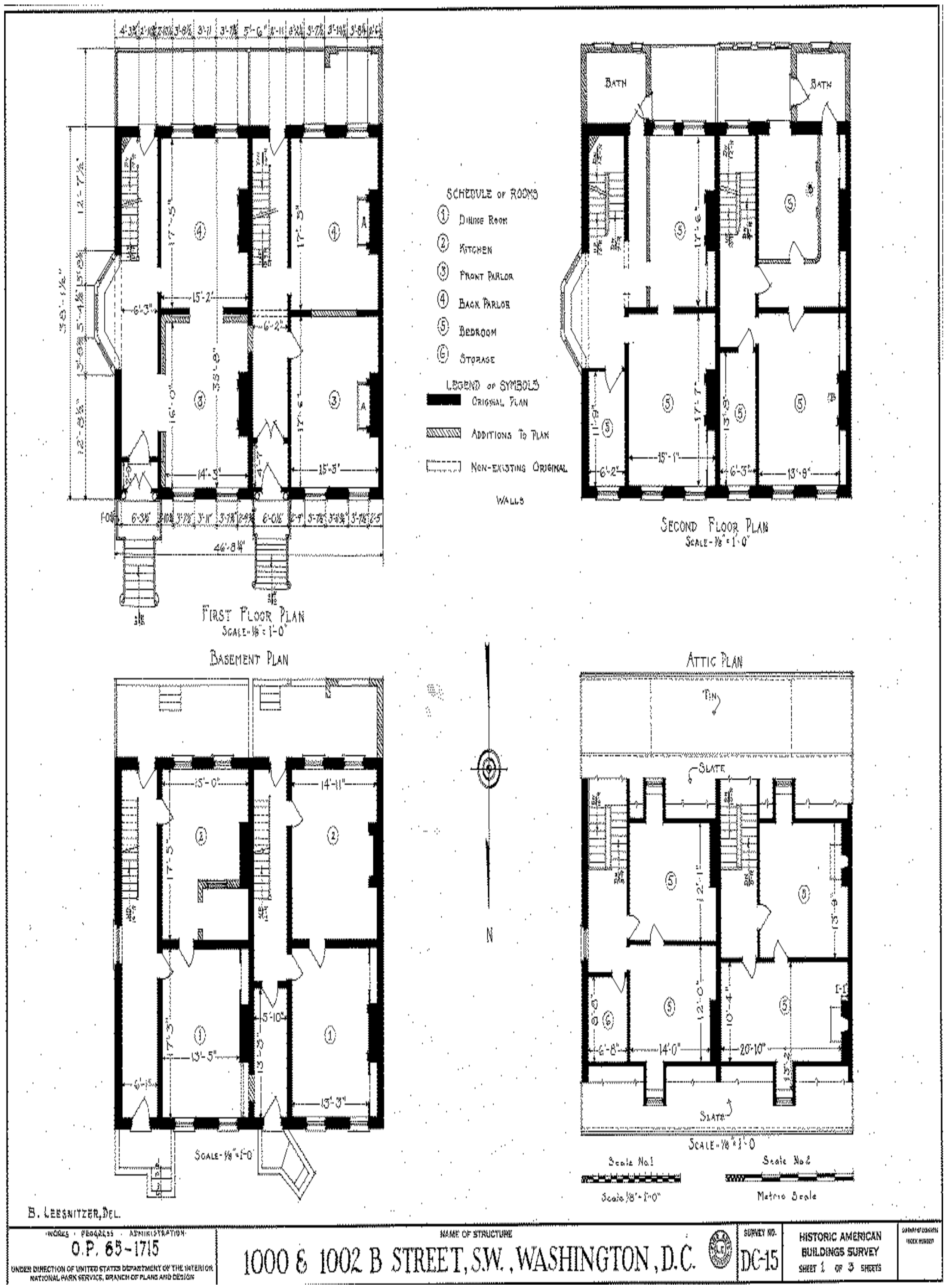
3-D Computer Analysis Case Study: "Capitol Row House A-E"

The 3-D model simulations were created to compare a typical historic ECRH of the Washington D.C. area that has undergone periodic renovations and upgrades throughout its life. Because every home is different and may have experienced a multitude of varied renovation and preservation project, the simulations represent a general sample based off historical trends. The objective of the models is to represent what an ECRH homeowner may expect to have or find in their historic building and the inefficiency results and costs of existing systems compared to a GHP Retrofit. The models are all based around one historic row house located at 1002 B Street S.W. Washington D.C (now Independence Avenue), Washington D.C. (Image 10 below, the second row house from the end), with the actual floor plans of that building obtained from the Historic American Building Survey (HABS).

106

Image 12

[106] "Historical Row Houses," Historical American Buildings Survey, accessed January 30, 2012, http://memory.loc.gov/ammem/collections/habs_haer/.



107

Figure 40

[107] Ibid.

The 1002 B Street ECRH was built in 1847 and is of the Federal style of architecture located within the Washington D.C. "Capitol Hill" Historic District. The square footage of the home lot measures 4,368 sq. ft. with 2,917 sq. ft. floor area and was constructed with no wall insulation and maintains plaster on the interior side of the walls. The 9 windows (6 in the front, 3 in the rear) are single pane, double hung without film or storm proofing. The roof/ceiling is a typical flat black roof with no insulation throughout the top. This particular ECRH was chosen to represent the typical 19th century ECRH suitable for present occupation as it meets the specifications and layouts that dominate the Washington D.C. historic districts and regional East Coast urban row house landscapes. As discussed in Chapter 2, the 19th Century marked the biggest boom in row house development whereby “the average urban row house was narrow, usually only 15-20 feet across, and extending back for 30 – 40 feet.”[108] This particular row house measures 20 feet – 10 inches wide and extends 38 feet deep meeting the typical row house dimensions. By the late 19th century, around the same time that this ECRH was built, the overall square footage expanded “between 2,200 and 2,800 sq. ft.… about the size of the typical home today (the standard home measurement in the United States is 2,349 square feet).”[109] This ECRH is slightly larger with 2,917 sq. ft. of living space making it that much more applicable as a model for a modern family desiring the space of a typical home but the character, quality and value of an ECRH. This particular row house is also located in a registered Historic District whereby applicable preservation codes and regulations for a retrofit would apply. Luckily, the Historic American Building Survey (HABS) had an original period photo and floor plans on file making the model renderings and analysis as close to realistic as possible.

For purposes of this study, this 1002 B Street ECRH in its computer model forms are referred to as “Capitol Row House” Model A, B, C, D, and E. Each model mimics

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[108] Moya Mason, “Housing: Then, Now, and Future,” accessed March 15, 2013, http://www.moyak.com/papers/house-sizes.html.
[109] “Standard House Measurements,” Dimensions Info, accessed March 15, 2013, http://www.dimensionsinfo.com/standard-house-measurements/.

the “Capitol Row House” floor plan and layout with progressive changes to the interior and utility systems:

- Model A – Represents the original construction with no insulation and minor interior upgrades. This model maintains a low 11.3 EER rating, split package gas/electric system and represents the base by which all other models will be compared.
- Model B – Represents Model A with the 11.3 EER rated gas/electricity split but with added insulation and improvements to the thermal envelope to identify the impact that thermal envelope improvements can have to an ECRH. This configuration is the most common scenario found in a historic ECRH inhabited today based off the secondary research outlined in Chapter 2.
- Model C – Represents Model A but with an upgraded installation of an 17 SEER rated electricity system that supplies the full utility needs alone. This configuration is included to show the higher end of a conventional system upgrade and the cost/savings that a homeowner may encounter.
- Model D – Takes the same configuration of Model C with the improved SEER 17 rated electricity system but with added preservation and thermal envelope improvements for maximized benefits with a conventional system.
- Model E – Represents Model B, the most common ECRH configuration, but with GHP integration that supplements and reduces the operation requirement of the existing gas/electric system. Model E will be compared to all of the models using Model A as the base configuration to substantiate the validity of this research.

The programs used to draft and analyze these models were *REVIT Architecture 2013* and the *Water Energy Distributors, Inc. Cost Calculator* created by Carl D. Orio, a certified Association of Energy Engineers (AEE) and GeoExchange Designer.[110] Due to the non-standard nature of the GHP system, conventional modeling tools such as *REVIT* and *EcoTect* do not have the analysis capability to incorporate GHP. However, the *Water*

[110] Carl D. Orio, “Water Energy,” Water Energy Distributors Inc., accessed March 15, 2013. http://www.northeastgeo.com/index.cfm/about-us/employee-information/carl-d-orio-ceo-founder/.

Energy Cost Calculator is an AEE certified tool utilized to provide energy cost comparison utilizing the same HVAC industry performance factors and inputs used by *REVIT* for the analysis of Models A-B. Once the structural and system parameters are input to the programs, the output is an extensive cost, usage, and efficiency analysis for comparison. The cost is analyzed utilizing actual energy charges in the Washington D.C. area during the peak period of February 2013 and July 2012 for cooling. Section 3.3 provides a summary of the analysis and the definitions of the program modeling study (refer to Appendix B for output Raw Data).

3.2 Qualitative Field Interviews

Of the 20 participants interviewed for this portion of the research, the average responses to each question are outlined below:[111]

1. What is your field of occupation and what do you consider your area of expertise?
   - 5/20: Architect and Engineers
   - 4/20: Real Estate professionals and Appraiser
   - 3/20: Academics specializing in Preservation
   - 4/20: Geothermal Professional Designers and Installers
   - 4/20: Homeowners of GHP Utilities

2. How familiar are you with residential energy consumption and utility systems?
   - All participants are familiar with residential systems and the costs associated with conventional energy sources, especially in the North East – MidAtlantic region.

3. What experience or knowledge do you have regarding alternative energy systems?
   - Majority of interviewees are proficient with Solar as an alternative source.

4. Specifically with regard to Geothermal Heat Pumps (GHP)?
   - Of the Architects, Engineers, and GHP Professionals, all are very familiar with the systems on a first hand basis. All GHP Professionals interviewed have completed several hundreds of installations and one installer has been developing patents since he started working on the GHP system in the 1980's. Another interviewee was a representative for multiple Geothermal companies for approximately 30 years. Of the Real Estate Professionals interviewed all conveyed little to no knowledge of GHP ultimately limiting them on answering many of the follow up questions.

[111] Majority of the participants interviewed agreed to be cited in this document. For protection of the anonymous, summary and paraphrasing of the total responses have been included. Refer to the Appendix B for interview and participation documentation.

5. What is your experience working or living in a historic residence?
    - All of the Architects and GHP professionals have completed projects or GHP installations on a historic building. Many expressed challenges to access and freedom of movement however all expressed satisfaction from their customers. All of the GHP professionals have successfully installed GHP systems into multiple historic projects throughout the Washington D.C. area including Baltimore and outlining counties. Experts on Preservation also had a diverse background on historic residential preservation needs and requirements.

6. What are the typical energy consumption issues and challenges to preservation?
    - Preservation, Architects: The most common challenges in historic residences relate to insufficient insulation, and poor thermal envelope seals due to windows, which is the typical source of the homes energy escape leading to an increased perception of consumption.

7. From your experience, compared to conventional utility sources such as gas, coal, wood, and electricity, how do Alternative energy systems such as GHP affect residential energy efficiency?
    - GHP Experts: Geothermal seems to have the biggest effect of the all the alternative sources. ‘Natural gas is cheap right now but quality of life still would outweigh the gas' benefits.’
    - Homeowner: ‘Uses 67% less electricity for cooling and there was no ductwork needed upon installation. Typically for heating [they] save between “55%-58%” with a GHP system.
    - ‘Coal is dirty and wood is just inefficient.’
    - Air exchange heat pumps can expect a max life of 15 years but will still need repairs. Additionally, once the outdoor temperature reaches 35 degrees you have to go to backup heat power and that means using fossil fuels or electricity to assist in providing heat from the air exchange unit.

- Homeowner: ‘GHP's are out of site and are not exposed to the elements, they carry anywhere from 25-50 year warranty and is more aesthetically pleasing. There is not the humming noise when outside trying to relax.

8. What are the benefits to sticking with conventional systems over new alternative systems?
   - Architects and GHP Installers: If there already is baseboard heating, radiant heating, it may be cost prohibitive to install because there may not be enough room in the walls due to the home only having plaster. It won't provide enough room for the pipes to come up.
   - GHP Installers: Sometimes there might be no way to install it if there is not enough space due to the need of the convective loop. However more times than not [we] can install it.

9. What kind of projects have you integrated GHP or similar alternative energy systems into?
   - 1921 Sears kit home
   - Section of 33 Historic Row houses
   - Historic Washington D.C. Navy-yard buildings

10. What are the benefits of doing an energy system, specifically heating retrofit on a residence (historic residence if applicable)?
    - You're taking low-efficient system and converting over to High-Efficient systems (Green systems if you will)
    - You can hook into a conventional duct work system or radiator system already in place
    - The federal tax credits offset the price and depending on local and county programs you will offset even more.
    - You will not need to replace until at least 25 years instead of 15 years for a conventional system.

- You do not have to worry about fossil fuel leaks or carbon monoxide; with coal, wood and oil you may have problems.

11. What are the challenges or pitfalls associated with these systems (for the firm, client, or contractors)?
    - Architects: Currently there are not a whole lot of experienced vendors so that could make it difficult should anything need repair.
    - Also architectural and structural, such as ductwork and a home that was built with minimal crawl space or on a slab then you run into issues logistically to get into the house. But besides that no real issues.

12. Are there any restrictions (Government, Civic, Historical, Logistical) that need to be considered before undergoing a retrofit?
    - Visual - historic residences are not allowed to have any identifying changes obvious to the façade for an observer. However with GHP there is no visibility issues which sets it apart from other alternative systems like Solar PVs that have to be exposed.
    - Some areas such as Bethesda (area just outside Northwest Washington D.C.), the arbor capital of the nation, you run into local permit issues that you have to get approvals for so that you do not disturb the tree roots or you may need to trim back and have an arborist to come in.
    - Environmental efforts are also a big item, sediment control and fluids control are key. [We] prefer to use a food grade glycol so if anyone drills for a new fence it will just be glycol spilling out.

13. What (if any) are the outweighing benefits that make a retrofit a worthy investment?
    - Sticker shock and lack of education or confidence are the items that stop many people from investing
    - Because these [historic] structures are inefficient you can reduce your bills by more than 50%

14. What are the typical costs and installation times to complete a utility (GHP) retrofit?
    - Depends - the cost and time vary on the square footage of a home, drill/installation accessibility, and permit requirements per project. Ideally cost should not a factor in this decision, because there is always a payback.

15. What are the expected investment returns and time expectancy to see the return on a retrofit?
    - 7-10 years depending on the size of the house and depending on the refunds and tax benefits that are there.
    - Homeowners: Personal estimates have been 4-6 years, but all energy costs are different in potential locations and usage.

16. How does a utility retrofit such as a GHP affect property values?
    - Homeowner: no specific study or appraisal has been conduct on their home, however they feel very confident it has made a positive effect and will help the resale value.
    - Real Estate Professionals: Many do not have a direct knowledge or figures but state many agents are promoting homes with copies of current owner utility bill findings. They first show the surrounding homes utility bills then pull out the bills of the home that is up for sale and typically does increase in value or at least the desire to purchase.
    - More training and exposure to the real estate field will increase the spread of knowledge to home buyers and market appraisers.

17. What are the typical responses and reactions of clients through the beginning, middle, and end of the retrofit process?

- Typically the responses for the beginning seem to be wary - customers are cautious about the different and ‘new’ technology of the system and the upfront costs.
- During the process customers do not like seeing the ground get messed up and then having to pay for grass to go down where they had it is a normal trend.
- One response from a woman showed how the system works properly, she called to ask if it was working saying "it doesn't get really hot as it did with my old furnace when I turned it up and it doesn't get really cold as when I use to turn it down" to that the installer replied "well are you comfortable?...yes (replied the customer)..." then it's working!"[112]

18. What government or civic benefits are there for completing an energy system retrofit?
    - There is at least a 30% tax credit right now that lasts until 2016, Maryland at one time was giving it out by the tonnage, but the policies and specifications vary as more updates and research is conducted.

19. Who (Commercial, industrial, residential clients) do you think would most benefit from a GHP retrofit?
    - In this order: Commercial, Institutional, Residential

20. For residential clients, do you see an advantage or disadvantage to installing this system in a historic Row House/Townhouse compared to a single family home?
    - The same benefits - lower costs when living in a row house however proximity to others and hearing their units ‘hollering’ all summer would be unsettling.

21. Especially for endangered historic residences, would conducting a utility systems retrofit be practical for preservation and sustainability of the building?

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[112] Interview - Bill Giuzzardi.

- Yes, because a typical system is wasting energy and produces more CO_2 that can be detrimental to the building as well as the occupants.
- For the historic residences that are registered and accessible to public funded money, a long term sustainability and operating costs investment would be very appealing.

22. Geothermal heating/cooling systems are slowly growing in popularity but not as fast as other alternative systems. From your experience what do you think the reasons are for the slow growth/integration into residences?
    - Advertising helps, there has been a steady growth of 30% a year for the last eight years so tax incentives certainly assist in a good portion of that.
    - Also most people understand electricity, solar is a lower buy in cost. Heating and cooling is more mysterious to the consumer. With GHP it is a much more difficult concept.

23. What do you think could improve the awareness and exposure of GHP for homeowners in the market for utility savings and improvements?
    - People have to see their neighbors use it, if they see it is not scary that proves it to them and helps to convince them.
    - Advertising again – if there is more on public service announcements and publicizing in and around the project sites, passersby's may ask questions to the installers and be intrigued.

The interviews of field professionals proved to be a valuable addition to this research. Pooled from various fields relating to the topic and the target audience, a majority of the responses were positive toward the integration of a GHP retrofit in a historic residence. Limitations of access of homeowners, particularly of historic ECRHs hampered the desired first hand qualification from homeowners. However, hearing from other GHP homeowners, experienced GHP installers, preservation experts and Architects that have worked on historic ECRHs validates the researched feasibility for a GHP retrofit to be accomplished and installed successfully with minor limitations or exorbitant costs.

3.3. 3-D Computer Analysis Case Study

The "Capitol Row House" models created and analyzed by *REVIT Architecture 2013* and the *Water Energy Distributors Inc. Cost Calculator,* take the structural and current energy system inputs to create cost, usage, and efficiency assessments. The cost is computed based off actual utility charges in Washington D.C. during the peak period of February 2013 and July 2012 for cooling. The *Water Energy Cost Calculator* is an AEE certified tool used for Model E that incorporates a specific GHP system and provides a cost comparison of conventional energy sources with geothermal using standard industry engineering HVAC performance factors.[113] Below is a summary of the computations and computer analysis definitions created to provide a comparative analysis of various ECRH utility situations:

- Location of Model: The first section of analysis shows the location of the model and average degree temperatures for the area. Also listed is the square footage of the home based of the "Capitol Hill Row House" inputs. The system takes inputs for lighting power, set to a low of 0.45 W/ft^2 and an occupation of 4 people, to represent a typical family size trying to keep energy costs down.

- EUI(Energy Use Intensity): This area describes the amount of energy in electricity and fuel requirements for the home. The sum is in kBtu's/sf/yr, which means 1,000 British Thermal units for analysis of the average output of the installed system.

- Life Cycle Energy Use/Cost: This analysis shows the total output and cost to expect over a 30 year period and *ideally* before a new replacement to the existing system should be made. It measures kWh/Therms per hour and calculates for the user the actual amount needed to run based off actual local prices on the date the analysis was conducted.

[113] "Water Energy Cost Calculator," Water Energy, accessed March 15, 2013 http://www.northeastgeo.com/index.cfm/homeowners/homeowners-workroom/calculate-cost-savings/.

- Annual Carbon Emissions: The Carbon Emissions are shown in the graph to show how much Fuel and Electricity in CO_2 emissions the home produces in tonnage per year.

- Annual Energy Use/Cost: The graph displays the annual charges for a homes electricity and fuel charge. This annual number takes into account all energy that the home will require which a majority typically for heating and cooling.

- Energy Use: Fuel: This is a "fuel" based graph, comparing the primary utility system (gas, oil, coal) in the home over electricity.

- Energy Use: Electricity: Similar to the fuel graph however this analysis shows the home usage with electricity primary measured in kilowatts(kWh).

- Monthly Heating/Cooling Load: These two graphs show where a homeowner can expect heating and cooling units to come from within the structures surrounding environments. The graphs will depict the walls as “heating negative” that represents poor insulation and high escape rate that results in negative BTU's. Likewise, the graphs will depict where cooling is being assisted or hindered.

- Monthly Fuel and Electrical Consumption: These two graphs are meant to show the difference between the systems and the amount they each depend on individually.

- Monthly Peak Demand: These graphs show the amount of energy for each utility system at its average peak throughout the months.

For purpose of summary, the next section extracts key graphs and figures that represent the best analysis of output/consumption efficiency, costs and savings to best compare each model as it relates to the topic of this research.

“Capitol Row House” Model A:

Stats/Figures
Location: Washington D.C.
Floor Area: 2,917 sf
Wall Type: Brick/Plaster
Insulation: None
R/U factors: Roof: R-0 (Wood frame roof (U=0.8515)
Utility Heat/Cooling System: Gas/Electric

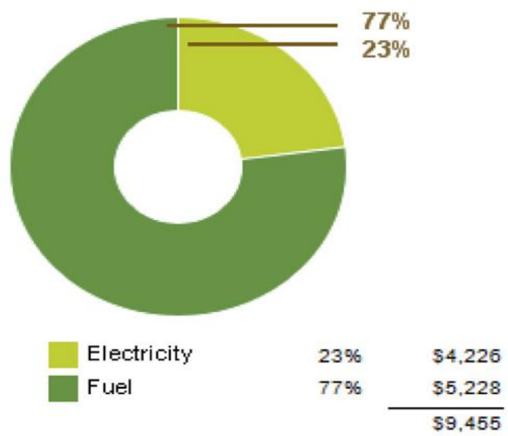
Description for Setup: This model represents the most basic configuration that a homeowner might expect for an ECRH with very little modern utility upgrades or preservation changes.

Costs and Savings:

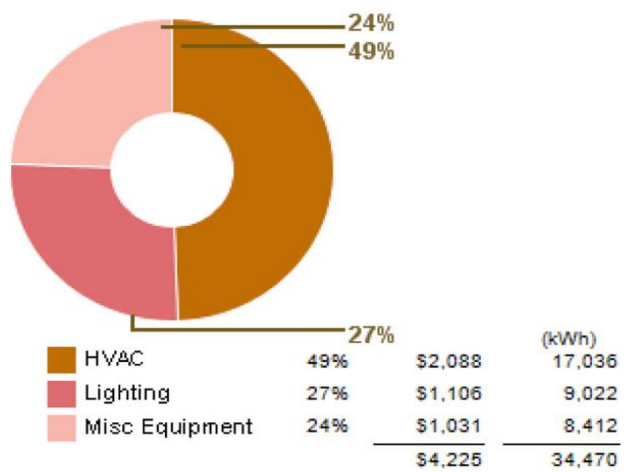
Electrical Cost: $0.12/kWh
Fuel Cost: $1.32/Therm
Life Cycle Electricity Use: 1,034,151 kWh

Electricity CO2 emissions: 31 tons/yr.
Fuel CO2 Emissions: 22 tons/year
Life Cycle Fuel Use: 118, 828 Therms

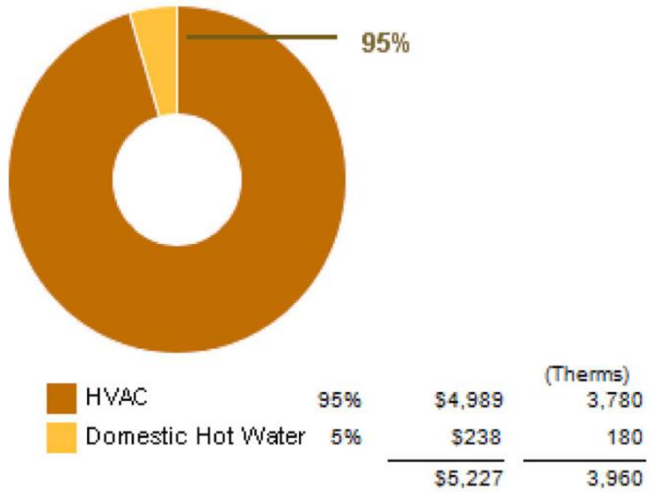
Graph 1: Annual Energy System Costs
This graph shows the percentage of energy costs between the electrical and gas systems with the gas/fuel comprising 77% of the total. The annual costs figures are based on real energy charges that are predominant in the Washington D.C. area at the time of analysis.



Graph 2: Distribution of Electricity Costs
Of the total electricity utility costs, HVAC, in this case heating from Gas/Electricity, makes up half of all the electric consumption cost at 49%. This is expected based off the research that majority of utility expenses go towards heating and cooling.

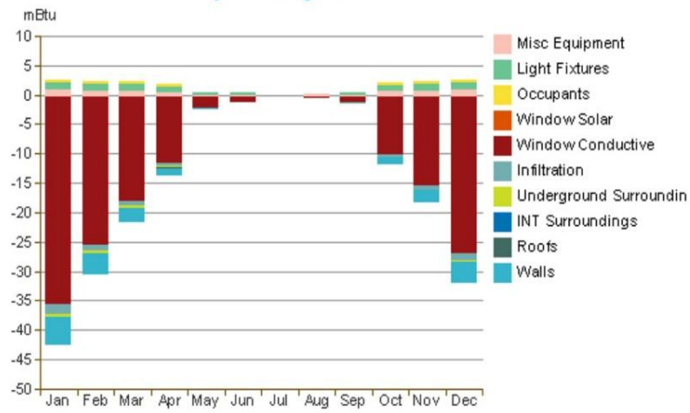


Graph 3: Heating Fuel Contribution
This graph details the amount of fuel (gas) used for space heating and hot water consumption. 95% of heating is devoted to HVAC which keeps in line with the previous electricity distribution.

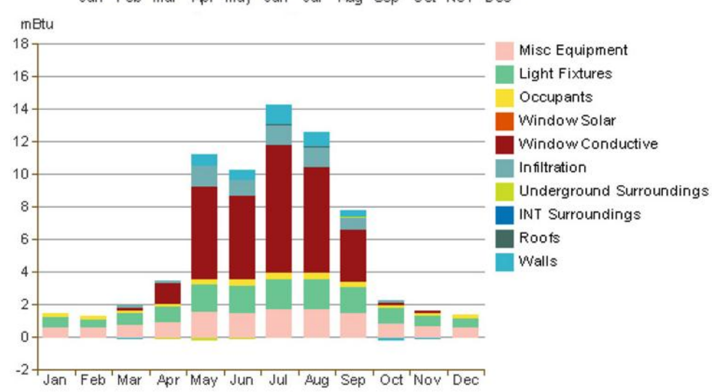


Energy Demand/Efficiency

Graph 4: Monthly Heating Load
This graph details the amount of energy the home consumes throughout the year, with the peak periods during the winter/cold months. Because of the poor insulation of this ECRH, majority of the heat escapes from the windows and walls.



Graph 5: Monthly Cooling Load
For cooling, the peak periods of consumption are during the summer months whereby poor insulation in the walls and windows further dissipate the cool air. Additionally, the added heat of older lighting/electricity units creates more heat that affect the cooling inefficiency.



Summary Assessment

This computer analysis quantifies the information obtained from the literature review and professional testimonies. For a historic ECRH with a low 11.3 EER rated Electricity/Gas split system and no insulation, the overall annual utility costs are $9,455 with a low efficiency of 11.3 EER. Additionally, the poor insulation of the windows and walls contribute to the most heating and cooling escape resulting in the higher overall costs.

Capital Row House Model B:

Stats/Figures

Location: Washington D.C.

Floor Area: 2,917 sf

Wall Type: Brick, R-5 Insulation board, sheathing gypsum (U=0.1006)

R/U factors: Roof: 4 in. wood with 2 in. Insulation (U=0.1509)

Utility Heat/Cooling System: Gas/Electric

Description for Setup: This model takes the same utility configuration as Model A but improves the thermal envelope with better insulation. This gas/electric split with insulation is the most common configuration for an inhabited ECRH.

Costs and Savings:

Electrical Cost: $0.12/kWh

Fuel Cost: $1.32/Therm

Life Cycle Electricity Use: 975,926 kWh

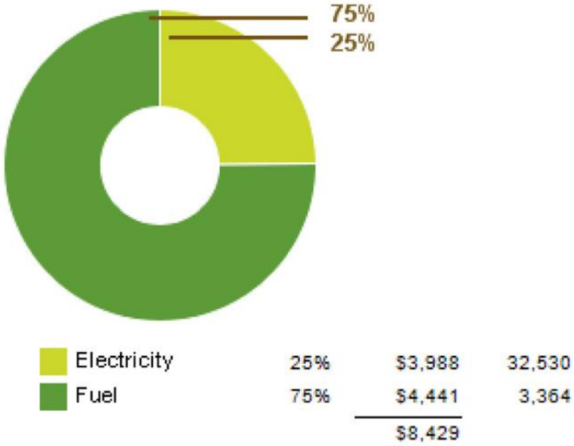
Fuel CO_2 Emissions: 19 tons/yr

Electricity CO_2 Emissions: 29 tons/yr.

Life Cycle Fuel Use: 100,923 Therms

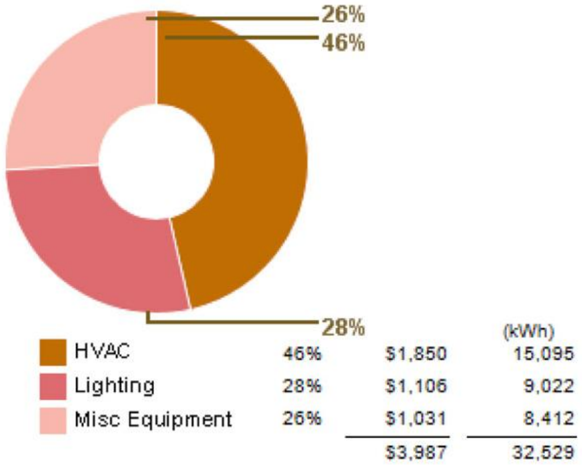
Graph 6: Annual Energy System Costs

The annual energy consumption and cost between gas and electricity is roughly the same with a slight 2% decrease of fuel and 2% increase for electricity compared to Model A. This small change does however result in a $1000 decrease in cost over the year.

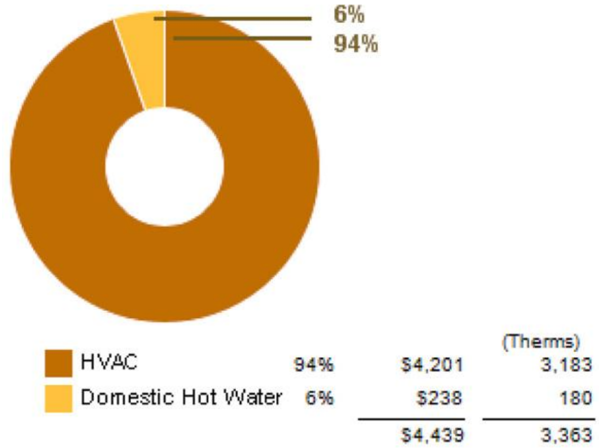


Graph 7: Distribution of Electricity Costs

Again, compared to Model A, the electric utility consumption and cost are slightly affected with a decrease in HVAC heating by 3% and a total 3% increase in lighting and misc. equipment. The result is a $238 savings just by improving the homes insulation.

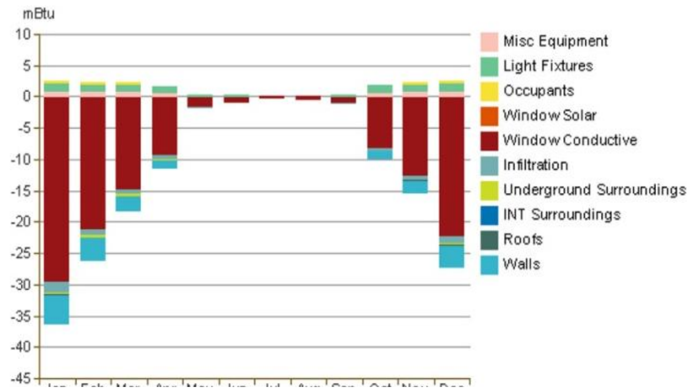


Graph 8: Heating Fuel Contribution
The fuel heating consumption had a slight 1% decrease for space and a 1% increase for water. Because the water uses 3003 less therms, the result is a savings of $788. This is an impactful as it shows the domino effect of how insulating the house can redistribute the fuel usage toward the needed systems resulting in improved efficiency.

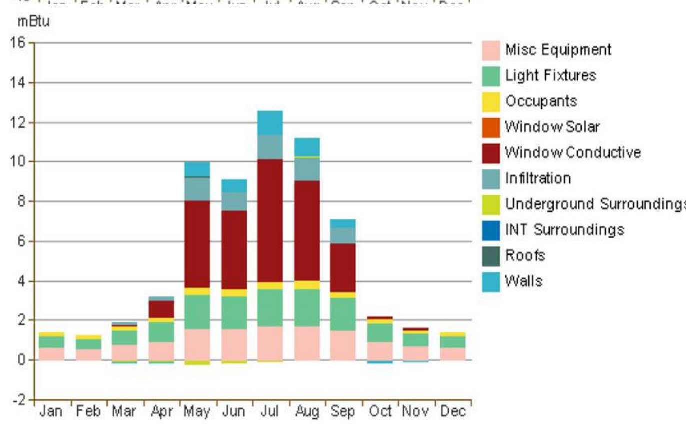


Energy Demand/Efficiency

Graph 9: Monthly Heating Load
By improving the insulation, the heating usage dropped by almost 10 mBtu. An improvement that was reflected in the cost savings, however the walls and windows still contribute to the greatest amount of consumption thereby requiring a higher rating of insulation improvements.



Graph 10: Monthly Cooling Load
The insulation improvements had a smaller affect on the cooling efficiency, resulting in a 1.75mBtu change. A potential reason for this may be the increased use of electricity over fuel to maintain the cooling requirements of the home.



Summary Assessment

Adding insulation to the row house provided the home with more energy efficiency compared to the non-insulated Model A. Added insulation saved the home $1026/yr, bringing the total cost down to $8,429/yr. Despite the savings, over $8,000/yr is still a high cost to pay for heating/cooling and matches with the typical ECRH configuration. Model C explores an ECRH with an upgraded SEER 17 electricity only solution.

Capital Row House Model C:

<u>Stats/Figures</u>
Location: Washington D.C.
Floor Area: 2,917 sf
Wall Type: Brick/Plaster
Insulation: None
R/U factors: <u>Roof:</u> R-0 (Wood frame roof (U=0.8515)
Utility Heat/Cooling System: Electric

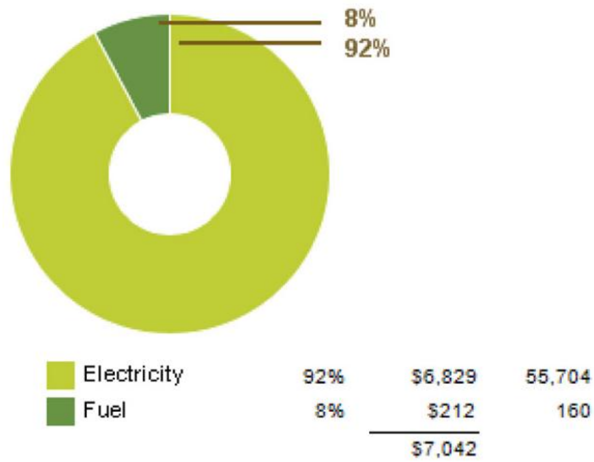
<u>Description for Setup:</u> This model analyzes the benefit of upgrading the utility system to a 17 SEER Electricity only system with no envelope improvements.

<u>Costs and Savings:</u>

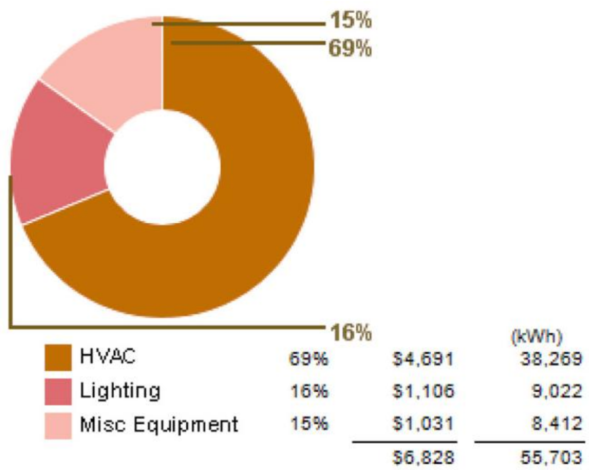
Electrical Cost: $0.12/kWh
Fuel Cost: $1.32/Therm
Life Cycle Electricity Use: 1,671,146 kWh

Electricity CO2 emissions: 50 tons/yr
Fuel C02 Emissions: N/A
Life Cycle Fuel Use: 4,823 Therms

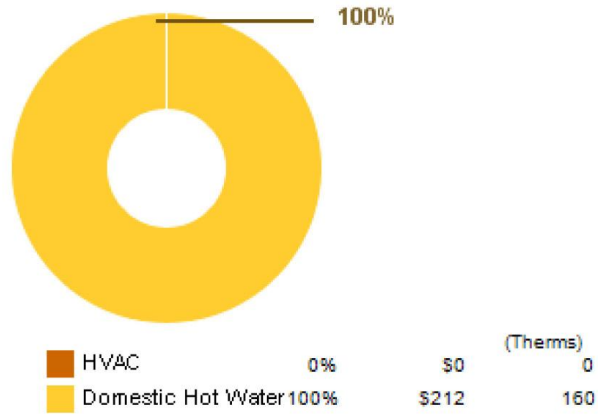
<u>Graph 11: Annual Energy System Costs</u>
Due to an electricity dominant utility system, the energy usage/cost have switched with Electricity at 92% and fuel (supplemental gas for domestic water heating) only 8%. By making this switch away from fuel, the homeowner saves $2413/yr.



<u>Graph 12: Distribution of Electricity Cost</u>
Compared to Model A, the HVAC has jumped 20% with an energy increase of 21,233kWh. The result is an increase of electricity consumption cost by $2603. This increase is expected as the fuel no longer supports the energy requirements of the HVAC system and the kWh amount to supply the additional systems remained the same.

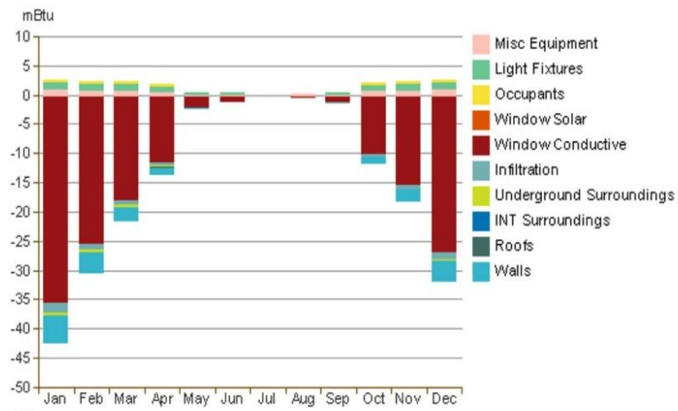


Graph 13: Heating Fuel Contribution
This graph depicts the full distribution of the 8% of fuel toward domestic hot water heating since it no longer supports the HVAC system. Even though the fuel continues to support water, the cost decreases by $26/yr.

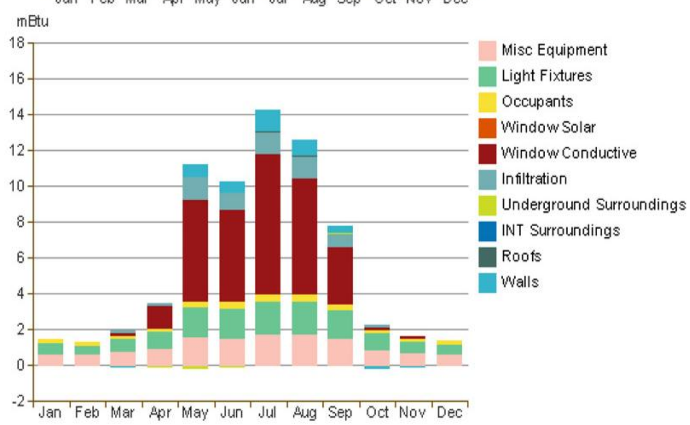


Energy Demand/Efficiency

Graph 14: Monthly Heating Load
The homes heating consumption remained the same as Model A there were no changes made to the thermal envelop to reduce energy consumption.



Graph 15: Monthly Cooling Load
Like Graph 14, the monthly cooling consumption remained the same as Model A due to no changes made to the thermal envelop to reduce energy consumption.



Summary Assessment

Compared to Model A, switching to an electricity only utility source saved the homeowner $2413/yr, bringing the overall energy cost to $7,042. This is an increase in savings compared to Model B that incorporates thermal envelop improvements. Model D will further assess the impact of an electricity only system with improved insulation for an example of best conventional energy efficiency scenario.

Capital Row House Model D:

Stats/Figures
Location: Washington D.C.
Floor Area: 2,917 sf
Wall Type: Brick, R-5 Insulation board, sheathing gypsum (U=0.1006)
R/U factors: Roof: 4 in. wood with 2 in. Insulation (U=0.1509)
Utility Heat/Cooling System: Electric
Description for Setup: This model provides a best case scenario for an ECRH equipped with a conventional electricity only system with moderate thermal envelope insulation upgrades.

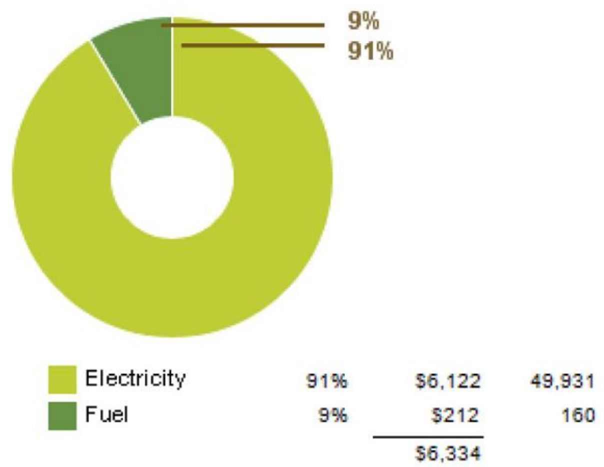
Costs and Savings:

Electrical Cost: $0.12/kWh
Fuel Cost: $1.32/Therm
Life Cycle Electricity Use: 1,497,941 kWh

Electricity CO2 emissions: 44 tons/yr
Fuel C02 Emissions:0 tons/yr
Life Cycle Fuel Use: 4,823 Therms

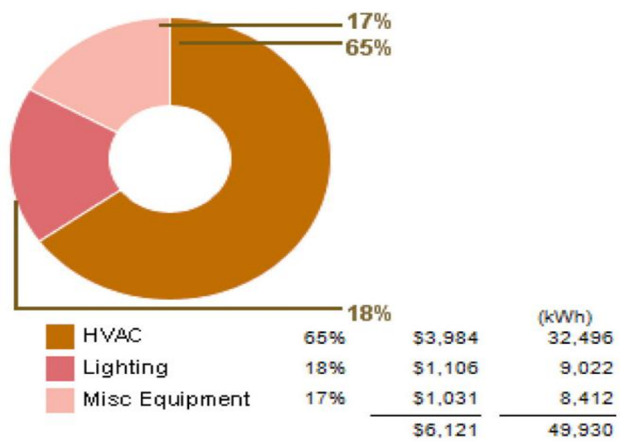
Graph 16: Annual Energy System Costs

Like the change between Model A and B, insulation upgrades only change the energy costs by decreasing electricity by 1% while the amount of fuel used remains the same at 160 therms. This results in a $708 annual cost savings compared to Model C without the insulation improvements.

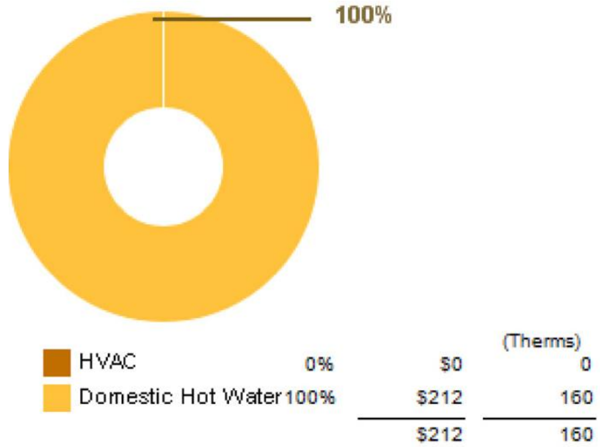


Graph 17: Distribution of Electricity Cost

The distribution of electricity toward HVAC decreases 3% which is the same change experienced between Model A and B when insulation was added. The electricity cost savings is $707, the bulk of the overall annual savings amount.

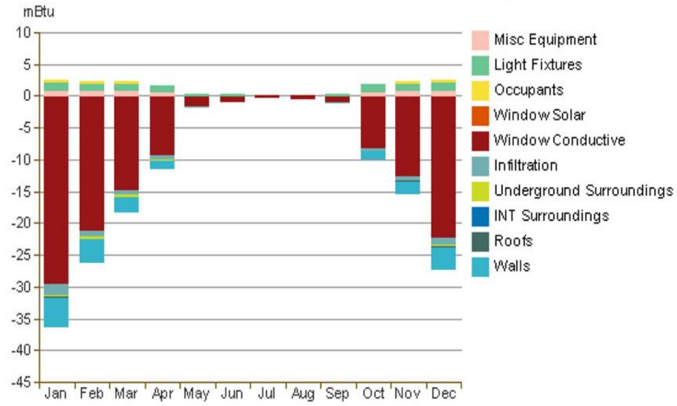


Graph 18: Heating Fuel Contribution
Fuel consumption remained the same with insulation providing no carry over benefit as in Model B because fuel has no role in this model's HVAC energy supply.

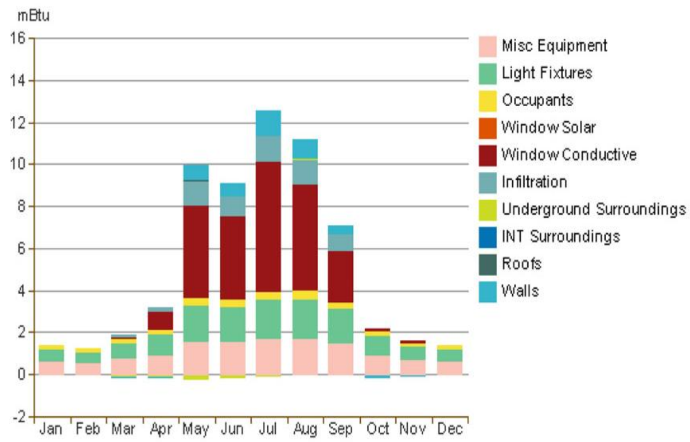


Energy Demand/Efficiency

Graph 19: Monthly Heating Load
As expected, the heating demand on the house improved with a reduction of 7 mBtu, resulting in greater efficiency for the electricity system,



Graph 20: Monthly Cooling Load
Like Model B's Graph 10, insulation has provided the same improvement to the cooling efficiency by 1.75 mBtu.



Summary Assessment

Of all the ECRH Models thus far, Model D with a SEER 17 electricity only system and improved insulation proves the best efficiency situation for the conventional utility scenario. Overall, Model D saves the homeowner $3,121/yr bringing the overall annual cost to $6334/yr. The final scenario in Model E, takes Model B (gas/electric split with moderate insulation) and incorporates a geothermal system as the dominant HVAC source to determine the most efficient system for the most typical ECRH situation.

“Capitol Row House” Model E:[114]

Stats/Figures

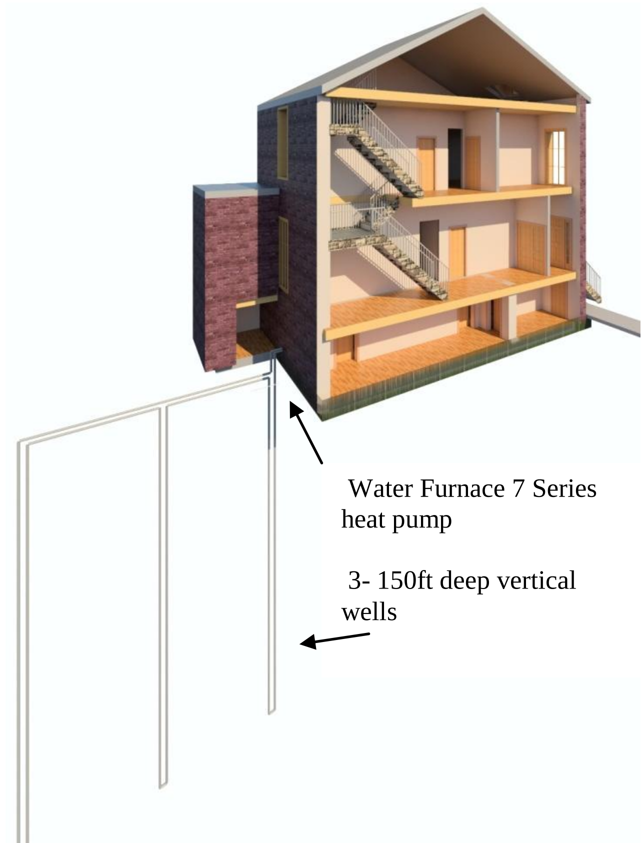
Location: Washington D.C.
Floor Area: 2,917 sqft
Wall Type: Brick, R-5 Insulation board, sheathing gypsum (U=0.1006)
R/U factors: Roof: 4 in. wood with 2 in. Insulation (U=0.1509)
Utility Heat/Cooling System: Gas/Electric → Geothermal Retrofit

Description for Setup: This model is an adaptation of Model B (the most common ECRH configuration) with a GHP retrofit inclusion. Model E incorporates the same moderate thermal envelope insulation improvement as Model B that has proven to increase efficiency throughout this research.

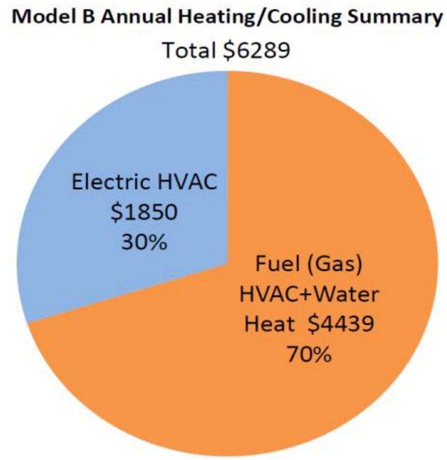
Costs and Savings:

Electrical Cost: $0.12/kWh	Life Cycle Electricity Use: N/A[115]
Fuel Cost: $1.32/Therm	Life Cycle Energy Cost: N/A
Fuel C02 Emissions: $0/yr	Life Cycle Fuel Use: $0/yr

The GHP system includes three vertical wells installed 150ft deep funneled to a *Water Furnace 7 Series* heat pump located in the basement.[116] This particular pump is incorporated to show the capacity of the top rated Energy Star GHP system for 2013.



[114] Due to the non-standard nature of the GHP system, *REVIT Architecture 2013* does not incorporate the system into its program for analysis. The *Water Energy Cost Calculator* is an AEE certified tool utilized to provide energy cost comparison utilizing the same HVAC industry performance factors and inputs used by *REVIT* for Models A-B.
[115] Life Cycle Costs were not included in the calculations due to the 50 year or greater extended life cycle rating of the GHP system whereby the cost figure would not be accurate over that period of time.
[116] *WaterFurnace 7 Series – 700A11 ARI13256 Geothermal Heat Pump, 2013 Energy Star Most Efficient.* http://www.waterfurnace.com/products.aspx?prd=700A11



Graph 21: Model B Annual Heating/Cooling Summary

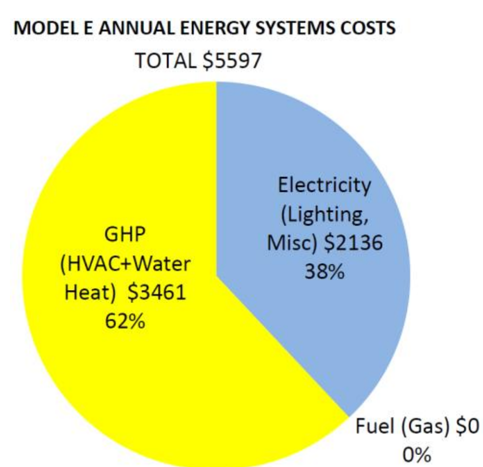
The overall annual heating and cooling costs for Model B were $6289 - $4439 for Fuel HVAC Heating/Water, and $1850 for Electric Cooling.

As GHP only supplements the heating and cooling, these base figures will be used as the base cost for the GHP comparison analysis.

Table 6: GHP Integration Cost Analysis

The *Water Furnace 7 Series* has a heating COP of 5.3 and cooling EER of 41 – both over the national average and contributing to its top Energy Star rating for 2013. The cost factors input to the Cost Calculator are peak utility rates for Washington D.C.

Geothermal Heat Pump with a Heating Efficiency* of	5.3	= TOTAL operating system efficiency/COP		
Geothermal Heat Pumps with a Cooling Efficiency* of	41	= TOTAL operating system efficiency/EER		
and local delivered electric utility costs of	$0.1200	per kWh (delivered) for Heating (Winter)		
*Use ISO-13256 Efficiencies (Includes pump correction factors)	$0.1900	per kWh (delivered) for Cooling (Summer)		
#2 FUEL OIL MUST cost or LESS than	$4.00	per gallon	*Heating*	
NATURAL GAS MUST cost or LESS than	$1.36	per CCF/gal.	*Heating*	(equivalent $1.32 per Therm)
PROPANE MUST cost or LESS than	$2.48	per gallon	*Heating*	
ELECTRICITY MUST cost or LESS than	$0.120	per kWh	*Heating*	
Air Conditoner Electric Must cost or LESS than	$0.130	per kWh	*Cooling*	*July 2012 rate - EIA*
Annual $ with #2 fuel oil		Computation for Geo vs. my Oil	$0	
Annual $ with Nat. Gas	$4,439	Computation for Geo on vs. Nat. Gas	$2,195	
Annual $ with Propane		Computation for Geo on vs. Propane	$0	
Annual $ with electric heat/hot water		Computation for Geo vs. my Elec. Heat	$0	
Annual $ with high SEER A/C	$1,850	Computation for Geo vs. my Elec. Cooling	$1,266	
Annual system maintenance cost		Annual Geo maintenance	$0	
TOTAL current annual heating/cooling/AC costs	$6,289	*Total estimated annual Geo cost*	$3,461	



Graph 22: Model E Annual Energy Systems Cost

The total annual heating/cooling cost with the integrated GHP retrofit would be $3,461. Electricity would still play a role in operating the pump, lighting, and miscellaneous support equipment throughout the home bringing the total Energy Cost to $5597. Compared to the base Model A, this would be a savings of $3858/yr – the greatest savings of all the Models.

- Assuming the average researched cost of installation and component purchase for a *Water Furnace 7 Series* of **$20,000** the following table breaks out the investment cost versus savings to project the return on investment (ROI):

Table 7: Projected Investment Return

Costs		Savings		Net Cost (Yr 1)	
Install (1 time)	$20,000	30% Tax Credit (1 time)	$9,000	Net Cost (yr 1)	$23,461
Operation/yr	$ 3,461	Operation/yr	$3,858	Net Savings (yr1)	$12,858
Total (yr 1)	$23,461	Total	$12,858	**Total (yr 1)**	**$10,603**
Investment Return Time (ROI)		**Savings/yr**	**$3,858**	**6.08 Years**	

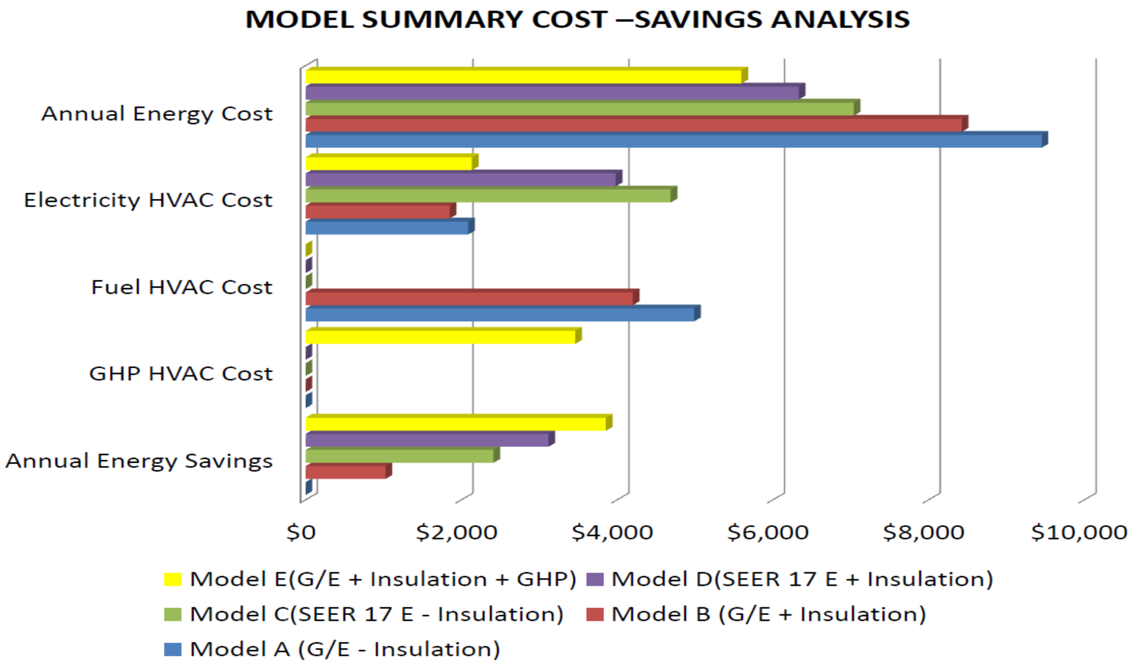
Summary Assessment

Model E successfully conveys the cost effectiveness and feasibility of a GHP retrofit installation in an ECRH saving the homeowner $3,858/ year, the highest savings of all the conventional models. The pre-insulation established with Model B was proven to increase efficiency and was therefore not evaluated again in this model however the cost figures from Model B were applied thereby reflecting the insulation benefit. The homeowner in this situation would save 41 percent of their annual utility cost and would see an investment return in just over 6 years assuming the average installation cost option for this type of house and selected GHP *Water Furnace 7 Series* Model.

“Capitol Row House” Model A – E Cost/Savings Summary:

Based off the analysis of each model, Graph 23 below summarizes the cost savings comparison of each model:

<u>Graph 23:</u>



The base Model A, the most basic ECRH situation of a gas/electric split system with no insulation, has the highest energy cost and is the basis for comparison with each successive model. Model B represents the most common ECRH configuration with the addition of low grade insulation and reflects the continual high annual energy costs faced by most ECRH homeowners. The system upgrade to a SEER 17 Electricity only system in Models C and D show significant decrease in the annual cost and higher savings but maintain the highest electricity costs that rely on plant processing and market fluctuation. Ultimately, Model E with the GHP retrofit of the gas/electric system and insulation found in Model B conveys the lowest annual cost and greatest overall energy savings. The overhead for purchase and installation does require an upfront cost but nets only $10,603 after rebates, tax incentives, and amount saved; comparably less than the overhead of an alternative conventional system. In summary, the “Capitol Row House” Model Case Study validates and supports the research that a GHP retrofit will improve the efficiency of an ECRH and provide cost savings by at least 40 percent with an ROI under 10 years.

4 Conclusive Summary: Results and Findings

To review, this research aimed to resolve the following questions:

- What are the efficiencies and costs of current space heating and cooling systems installed in most ECRHs?
- How can the ECRH historic and residential value be increased and the utility costs be decreased?
- What is the most viable space heating and cooling solution for a historic ECRH and how will it impact the homeowner in the long term?

The knowledge, data, and evidence substantiated in this research document successfully resolve the fundamental questions posed in the objectives. Below is a summary of the results and findings as they relate to the original research objectives.

4.1 ECRH Space Heating and Cooling - Cost Efficiency

Information obtained in this research convey that historic ECRHs were originally built with strong construction materials such as brick, designed to naturally withstand the effects of hot and cold temperatures. Over the years as technologies advanced and social needs of comfort expanded, most ECRHs underwent periods of utility system renovations and upgrades that were not in the original design of the building. Fast forward upwards of 50 to 100 years and many ECRH homeowners may find antiquated oil and propane furnace systems with no air conditioning, or more modern gas/electric systems with window box air conditioning and possible central air cooling. Despite renovation and improvement attempts, homes built before 1950 are considered at least 30% less efficient than homes built after 2000. Evidenced in this research is that conventional fuels used for space heating and cooling systems are not cost effective and only 75% efficient especially if the home is not properly insulated with thermal envelope improvements. Supported by the professional field interviews and applied 3-D computer analysis, ECRH homeowners are currently paying upwards of $6000 a year in space heating and cooling costs. The solution is tightening the thermal envelope with window, roof, and wall insulation upgrades as well as incorporating an alternative energy system such as GHP that will reduce utility costs by at least 40% and improve efficiency by approximately 400% with average heating COP ratings of 4 and cooling EER of 17.

4.2 GHP Applicability to East Coast Row House (ECRH) Preservation

The benefits of a GHP retrofit to a historic ECRH stem from the discreet nature of the system. Most preservation standards require that the historic building not be destroyed or disturbed with visible changes or additions that could cause future unintended damage to the structure. GHP systems are installed underground and may utilize the same ductwork already in place for some conventional systems. GHPs have the benefit of dual heating and cooling without separate ducting allowing less invasion or disruption to the house. Installation in small/tight urban areas is possible with compact drills so long as proper permits and code are maintained. GHPs use a fraction of standard electricity and is a *clean* system that emits minimal CO2 compared to conventional fossil fuel systems. The air circulating with a GHP system will have prolonged preservation benefits by reducing the toxic emissions and provide appropriate humidity controls that are vital to the integrity of most ECRHs. The "Greenspur" case study exemplifies the potential of a historic ECRH in need of preservation, and demonstrates "what is possible when you blend cutting edge sustainable practices, historical fabrics of the past with forward thinking design and innovation."[117] Now this home is revered as Washington D.C.s first carbon neutral home and in the top one percent of America's most efficient houses. "Greenspur" is a paradigm for ECRH preservation and proof that a GHP retrofit is a viable option.

4.3 GHP Investment Gain

Additional knowledge gained from this research is an awareness of government supported acts to facilitate the homeowner's quest for efficiency improvements and the high regard of GHP. The fact that the Federal government will rebate 30 percent of the

[117] Capitol Hill: Pre Civil War House to Carbon Neutrality," Archithings, accessed April 15, 2012, http://www.archithings.com/capitol-hill-pre-civil-war-house-to-carbon-neutrality/2010/02/01.

overhead costs and mortgage lenders are willing to incorporate the investment into the home equity, highlights the value and validity of a GHP retrofit for an ECRH. Several government and field experts quote annual savings of at least $1,500 with GHP integration. Taking into account the applied 3-D models for a typical historic ECRH, that savings can be even higher at over $3000 a year depending on the ECRH needs and extremes. The projected return on the initial GHP investment is cited between 5 and 13 years throughout this research, dependent on the situation of each home and the choices of the homeowners. This time range supports the initial estimate of return within 10 years and compounded with the knowledge that the GHP system is expected to last upwards of 50 years with little maintenance requirements, the additional investment return is substantial beyond a decade.

4.4 GHP Market Value

It is clear that the value of ECRHs is embedded in their historical features, residential function comprising 34 percent of East Coast homes, and their space efficient design for limited site areas. “The town house is unique as both a structural and spatial building type…efficient and economical to build…an individual unit capable of personal expression and the embodiment of an urban capacity to shape the public space of a city” (Gorlin, 9). Current market trends show that restored historic ECRHs in the heart of east coast city centers carry price tags well over $1 million. Feeding this trend, the *National Association of Realtors Appraisal Journal* estimates that a home's value “increases by $10 to $25 for every $1 reduction in utility bills.”[118]Home buyers are willing to pay more and thereby hold higher value to historic homes with efficient qualities and sustainable systems because it implies a smart investment for the future while owning a piece of living American history. A GHP retrofit is a safe and viable option for current or prospective historic ECRH homeowners looking to increase their homes market value while preserving the integrity of the home and live in a comfortable environment without a high cost burden.

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[118] Geo-Exchange Organization, "Geothermal Facts" Accessed April 15, 2012, http://www.geoexchange.org/downloads/GB-019.pdf.

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Appendix B. Applied Research Design Raw Data

Office of Research Compliance
Human Studies Program

UNIVERSITY of HAWAI'I
MĀNOA

February 5, 2013

TO: Carlos Lopez
Principal Investigator
School of Architecture

FROM: Denise A. Lin-DeShetler, MPH, MA
Director

Re: CHS #20976- "Geothermal Heat Pumps: Energy Efficient Heating Solution for the East Coast Row House"

This letter is your record of the Human Studies Program approval of this study as exempt.

On February 5, 2013, the University of Hawai'i (UH) Human Studies Program approved this study as exempt from federal regulations pertaining to the protection of human research participants. The authority for the exemption applicable to your study is documented in the Code of Federal Regulations at 45 CFR 46.101(b) (4).

Exempt studies are subject to the ethical principles articulated in The Belmont Report, found at http://www.hawaii.edu/irb/html/manual/appendices/A/belmont.html

Exempt studies do not require regular continuing review by the Human Studies Program. However, if you propose to modify your study, you must receive approval from the Human Studies Program prior to implementing any changes. You can submit your proposed changes via email at uhirb@hawaii.edu. (The subject line should read: Exempt Study Modification.) The Human Studies Program may review the exempt status at that time and request an application for approval as non-exempt research.

In order to protect the confidentiality of research participants, we encourage you to destroy private information which can be linked to the identities of individuals as soon as it is reasonable to do so. Signed consent forms, as applicable to your study, should be maintained for at least the duration of your project.

This approval does not expire. However, please notify the Human Studies Program when your study is complete. Upon notification, we will close our files pertaining to your study.

If you have any questions relating to the protection of human research participants, please contact the Human Studies Program at 956-5007 or uhirb@hawaii.edu. We wish you success in carrying out your research project.

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Biomedical Sciences Building B104
Honolulu, Hawai'i 96822
Telephone: (808) 956-5007
Fax: (808) 956-8683
An Equal Opportunity/Affirmative Action Institution

University of Hawai'i
Participation Information for Doctoral Research Project:
Geothermal Heat Pumps: Energy Efficient Heating Solution for the East Coast Row House
Researcher: Carlos F. Lopez, University of Hawai'i School of Architecture

Information and Purpose: The interview for which you are being asked to participate in, is part of a doctoral research study focused on the effects of Geothermal Heat Pumps (GHP) on the energy efficiency of historic East Coast Row Houses. The data collected from this research will be used to draw conclusions on the efficacy of GHPs as an energy efficient heating solution and identify the relevancy of system retrofits on the preservation of historic homes.

Your Participation: Your participation in this study will consist of an interview lasting approximately one hour. You will be asked questions relating to your field of occupation, your experiences working with or around alternative home energy systems, and your recommendations for energy efficiency solutions. Homeowners will be asked supplemental questions relating to utility costs and usage to better highlight the realistic application of home energy systems. Field professionals will also be asked for any quantitative data or records relating to their practical expertise that may facilitate the conclusive findings derived from the interview. For example, if you have worked on a specific case study relating to a GHP retrofit and have an energy analysis or specifications for the system that you would like to share, that contribution could greatly enhance the efficacy of this research.

You may pass on any question or request, and at any time may notify the researcher that you would like to discontinue your participation with no repercussion.

Benefits and Risks: Your participation in this research will contribute to the greater awareness of alternative energy efficiency solutions for East Coast homeowners who are faced with the highest energy costs in the country and are in greatest need for sustainable solutions. There are no risks associated with participating in this study.

Methodology: The interviews will be audio taped to supplement hand notes to ensure the researcher accurately captures your information. The tapes, notes, and any supplemental data you provide will be used only for the purpose of this study and will be maintained in the secure possession of the researcher. Once the audio recordings are transcribed, the audio recordings will be erased. Note that legally authorized agencies, including the University of Hawai'i Human Studies Program and School of Architecture have the right to review research records.

Confidentiality: Your personal identifying information will remain anonymous and a pseudonym Case Study name will be assigned for any project or supplemental data related to this research. However if you or your company prefer to be acknowledged and cited in the research document, please notify the researcher and proper annotation according to MLA standards will be applied. You have the right to withdraw from the research at any time whereby all information you provide will be omitted.

Contact Information: If you have any questions or concerns about this project, please contact me, Carlos Lopez, at: or by email at: . If you have any questions about your rights as a research participant in this project, you may contact the University of Hawai'i, Human Studies Program, at: (808) 956-5007 or by email at uhirb@hawaii.edu.

Thank you for your time and consideration, I look forward to any contributions you can provide to this research.

University of Hawai'i School of Architecture
Doctoral Research: Participant Interview Questions

Participant: ________________________ **Occupation:**________________________
Consent Date: ______________________ **Interview Date:**_____________________
Interview Method: In Person / Phone____ **Interview Location:**__________________
Interview Start Time:________________ **Interview End Time:**_________________

1. What is your field of occupation and what do you consider your area of expertise?

2. How familiar are you with residential energy consumption and utility systems?

3. What experience or knowledge do you have regarding alternative energy systems?

4. ... Specifically with regard to Geothermal Heat Pumps (GHP)?

5. What is your experience working or living in a historic residence?

6. What are the typical energy consumption issues and challenges to preservation?

7. From your experience, compared to conventional utility sources such as gas, coal, wood, and electricity, how do Alternative energy systems such as GHP affect residential energy efficiency?

8. What are the benefits to sticking with conventional systems over new alternative systems?

9. What kind of projects have you integrated GHP or similar alternative energy systems into?

10. What are the benefits of doing an energy system, specifically heating retrofit on a residence (historic residence if applicable)?

11. What are the challenges or pitfalls associated with these systems (for the firm, client, or contractors)?

12. Are there any restrictions (Government, Civic, Historical, Logistical) that need to be considered before undergoing a retrofit?

13. What (if any) are the outweighing benefits that make a retrofit a worthy investment?

14. What are the typical costs and installation times to complete a utility (GHP) retrofit?

15. What are the expected investment returns and time expectancy to see the return on a retrofit?

16. How does a utility retrofit such as a GHP affect property values?

17. What are the typical responses and reactions of clients through the beginning, middle, and end of the retrofit process?

18. What government or civic benefits are there for completing an energy system retrofit?

19. Who (Commercial, industrial, residential clients) do you think would most benefit from a GHP retrofit?

20. For residential clients, do you see an advantage or disadvantage to installing this system in a historic Row House/Townhouse compared to a single family home?

21. Especially for endangered historic residences, would conducting a utility systems retrofit be practical for preservation and sustainability of the building?

22. Geothermal heating/cooling systems are slowly growing in popularity but not as fast as other alternative systems. From your experience what do you thing is the reasons are for the slow growth/integration into residences?

23. What do you think could improve the awareness and exposure of GHP for homeowners in the market for utility savings and improvements?

24. Do you have any supplemental data or records from your experiences that can support your inputs and provide greater support for this research?

25. Do you have any further recommendations to enhance this research or referrals for further investigation?

26. Do you have any questions for me or requests in regards to this research?

27. Any voluntary comments from Participant:

~ End of Interview ~

Autodesk Revit Energy Analysis Report

CAPITAL ROW HOUSE

11.3 EER

Building Performance Factors

Location:	Washington, DC, USA
Weather Station:	48317
Outdoor Temperature:	Max: 94°F/Min: 5°F
Floor Area:	2,917 sf
Exterior Wall Area:	5,965 sf
Average Lighting Power:	0.46 W / ft²
People:	4 people
Exterior Window Ratio:	0.36
Electrical Cost:	$0.12 / kWh
Fuel Cost:	$1.32 / Therm

CAPITAL ROW HOUSE

11.3 eer with higher insulation

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CAPITAL ROW HOUSE

SEER 17

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CAPITAL ROW HOUSE
SEER 17 Higher Insulation
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CAPITAL ROW HOUSE
11.3 EER
Energy Use Intensity

Electricity EUI:	8 kWh / sf / yr
Fuel EUI:	95 kBtu / sf / yr
Total EUI:	123 kBtu / sf / yr

CAPITAL ROW HOUSE
11.3 eer with higher insulation
Energy Use Intensity

Electricity EUI:	8 kWh / sf / yr
Fuel EUI:	81 kBtu / sf / yr
Total EUI:	107 kBtu / sf / yr

CAPITAL ROW HOUSE
SEER 17
Energy Use Intensity

Electricity EUI:	13 kWh / sf / yr
Fuel EUI:	4 kBtu / sf / yr
Total EUI:	49 kBtu / sf / yr

CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Energy Use Intensity

Electricity EUI:	12 kWh / sf / yr
Fuel EUI:	4 kBtu / sf / yr
Total EUI:	45 kBtu / sf / yr

CAPITAL ROW HOUSE
11.3 EER
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	1,034,151 kWh
Life Cycle Fuel Use:	118,828 Therms
Life Cycle Energy Cost:	$128,772

*30-year life and 6.1% discount rate for costs

CAPITAL ROW HOUSE
11.3 eer with higher insulation
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	975,926 kWh
Life Cycle Fuel Use:	100,923 Therms
Life Cycle Energy Cost:	$114,802

*30-year life and 6.1% discount rate for costs

CAPITAL ROW HOUSE
SEER 17
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	1,671,146 kWh
Life Cycle Fuel Use:	4,823 Therms
Life Cycle Energy Cost:	$95,907

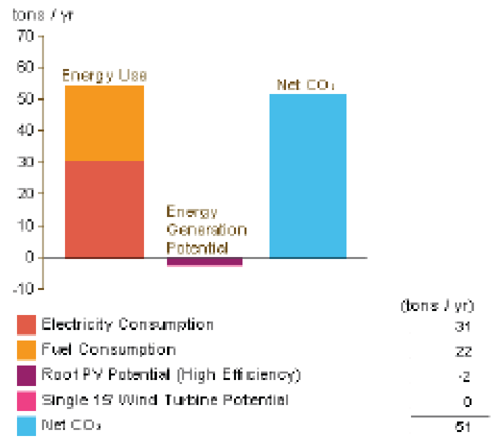
*30-year life and 6.1% discount rate for costs

CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Life Cycle Energy Use/Cost

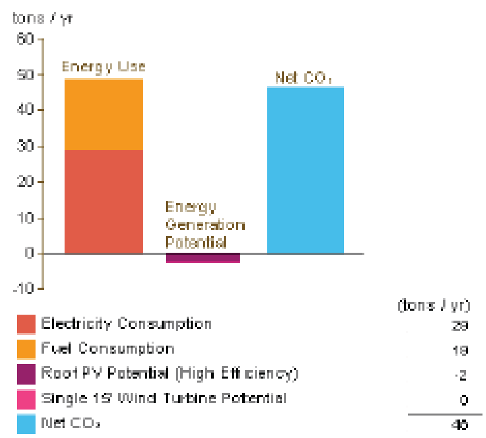
Life Cycle Electricity Use:	1,497,941 kWh
Life Cycle Fuel Use:	4,823 Therms
Life Cycle Energy Cost	$86,267

*30-year life and 6.1% discount rate for costs

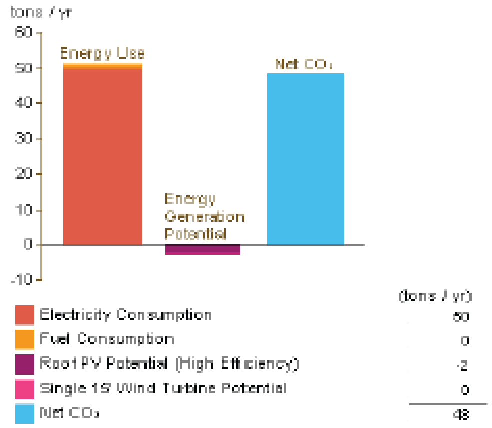
CAPITAL ROW HOUSE
11.3 EER
Annual Carbon Emissions



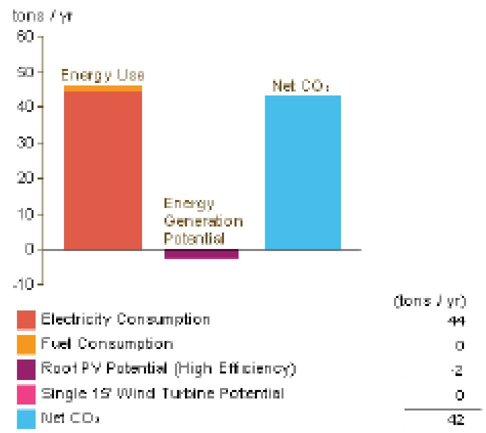
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Annual Carbon Emissions



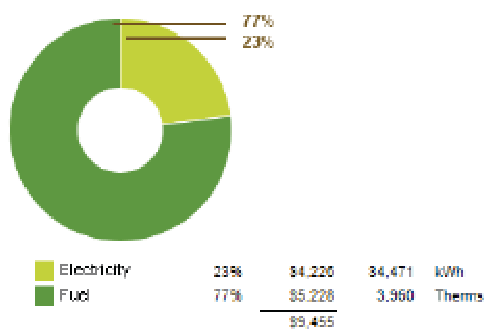
CAPITAL ROW HOUSE
SEER 17
Annual Carbon Emissions



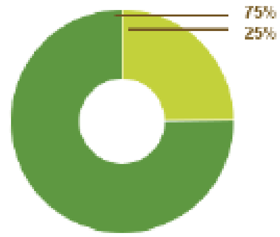
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Annual Carbon Emissions



CAPITAL ROW HOUSE
11.3 EER
Annual Energy Use/Cost

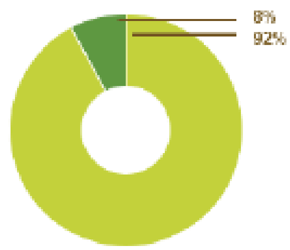


CAPITAL ROW HOUSE
11.3 eer with higher insulation
Annual Energy Use/Cost



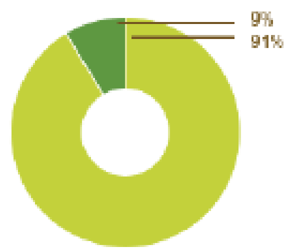
Electricity	25%	$3,988	32,530	kWh
Fuel	75%	$4,441	3,364	Therms
		$8,429		

CAPITAL ROW HOUSE
SEER 17
Annual Energy Use/Cost



Electricity	92%	$6,829	55,704	kWh
Fuel	8%	$212	160	Therms
		$7,042		

CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Annual Energy Use/Cost

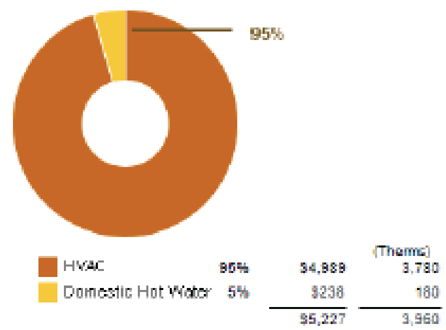


Electricity	91%	$6,122	49,931	kWh
Fuel	9%	$212	160	Therms
		$6,334		

CAPITAL ROW HOUSE

11.3 EER

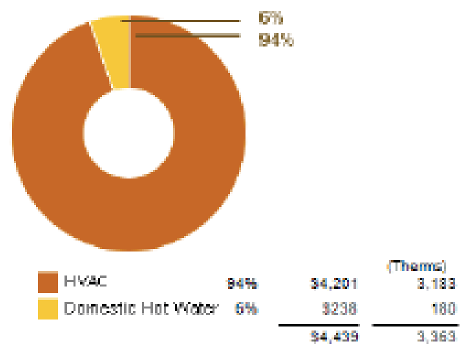
Energy Use: Fuel



CAPITAL ROW HOUSE

11.3 eer with higher insulation

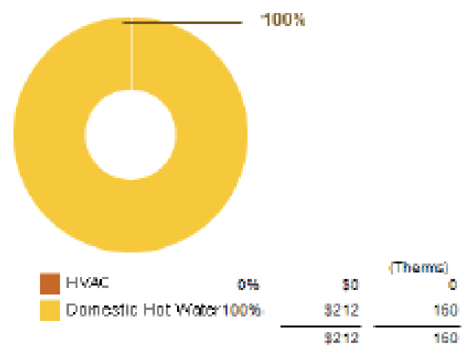
Energy Use: Fuel



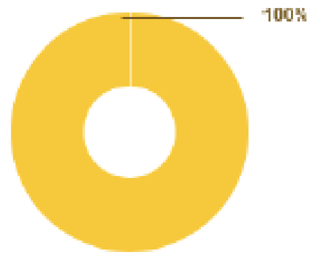
CAPITAL ROW HOUSE

SEER 17

Energy Use: Fuel

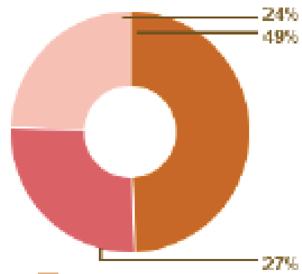


CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Energy Use: Fuel



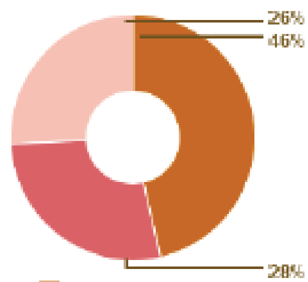
			(Therms)
HVAC	0%	$0	0
Domestic Hot Water	100%	$212	160
		$212	160

CAPITAL ROW HOUSE
11.3 EER
Energy Use: Electricity



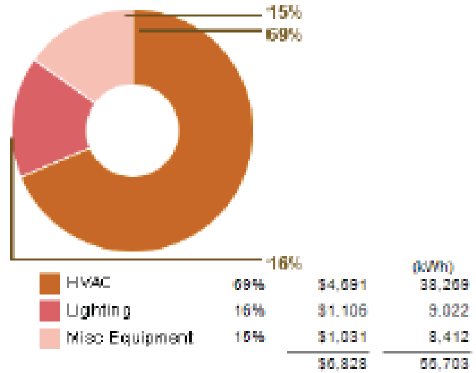
			(kWh)
HVAC	49%	$2,088	17,036
Lighting	27%	$1,106	9,022
Misc Equipment	24%	$1,031	8,412
		$4,226	34,470

CAPITAL ROW HOUSE
11.3 eer with higher insulation
Energy Use: Electricity

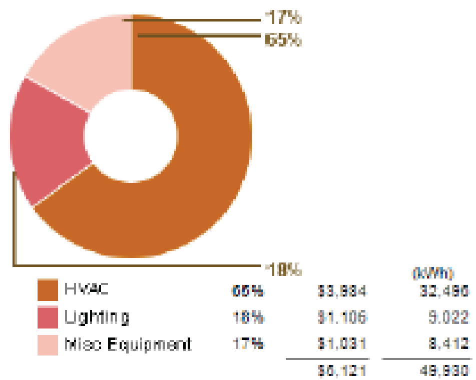


			(kWh)
HVAC	46%	$1,850	15,096
Lighting	28%	$1,106	9,022
Misc Equipment	26%	$1,031	8,412
		$3,987	32,629

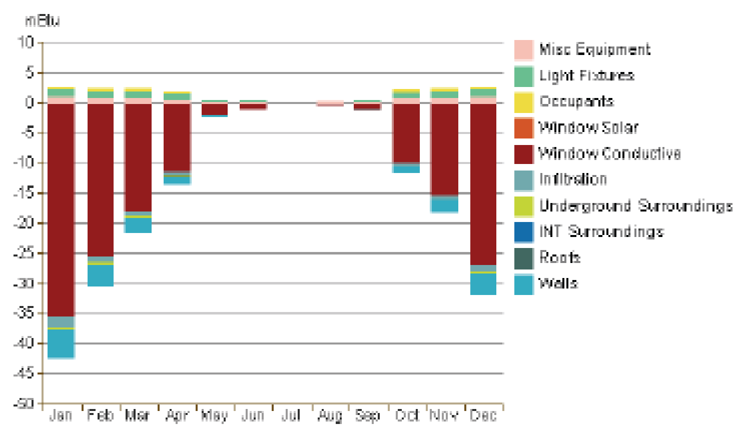
CAPITAL ROW HOUSE
SEER 17
Energy Use: Electricity



CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Energy Use: Electricity



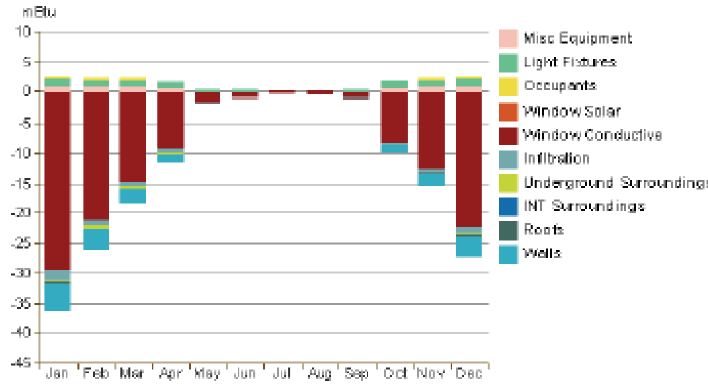
CAPITAL ROW HOUSE
11.3 EER
Monthly Heating Load



CAPITAL ROW HOUSE

11.3 eer with higher insulation

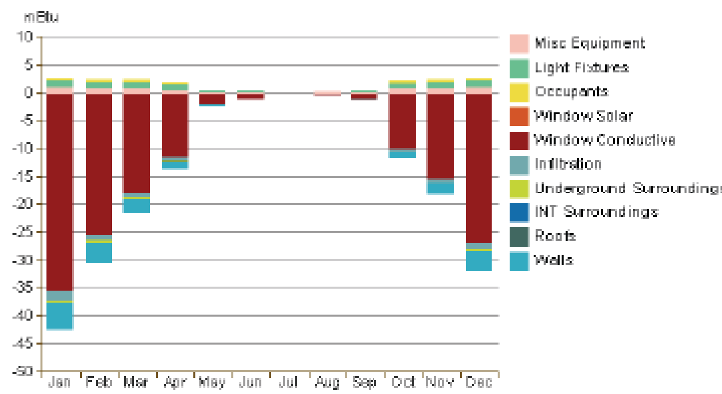
Monthly Heating Load



CAPITAL ROW HOUSE

SEER 17

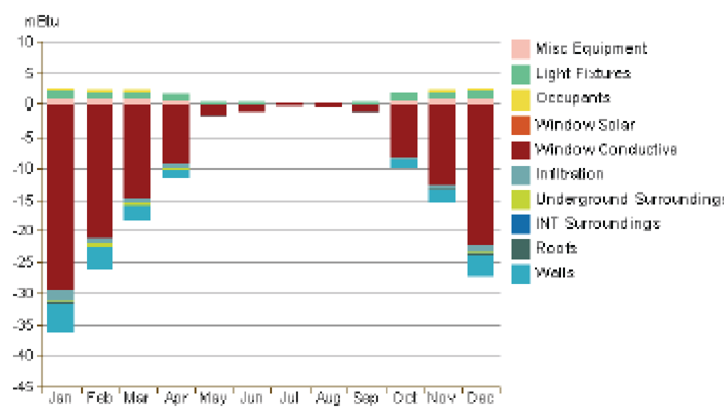
Monthly Heating Load



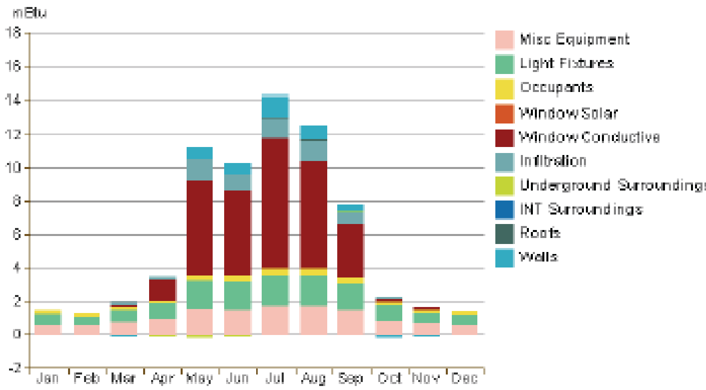
CAPITAL ROW HOUSE

SEER 17 Higher Insulation

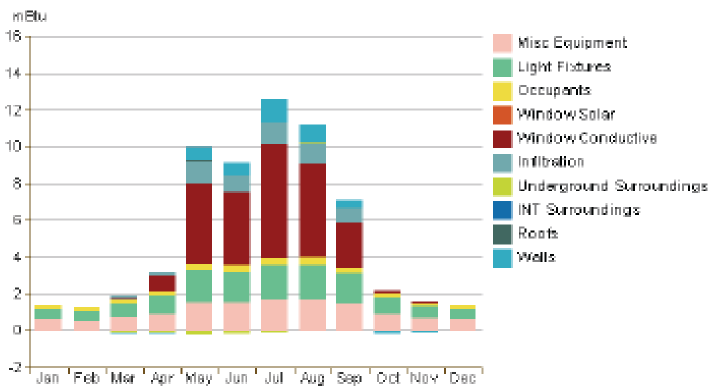
Monthly Heating Load



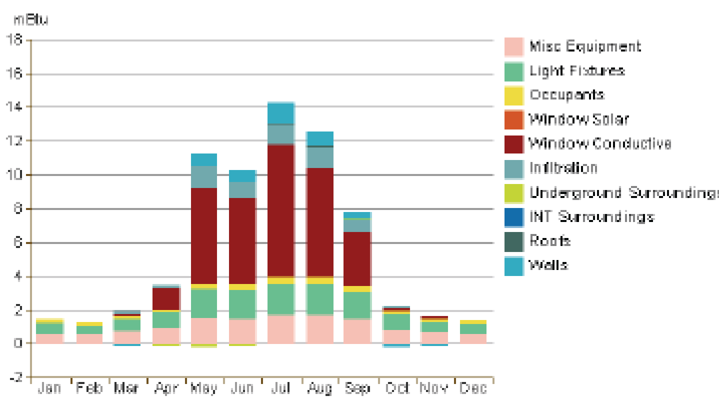
CAPITAL ROW HOUSE
11.3 EER
Monthly Cooling Load



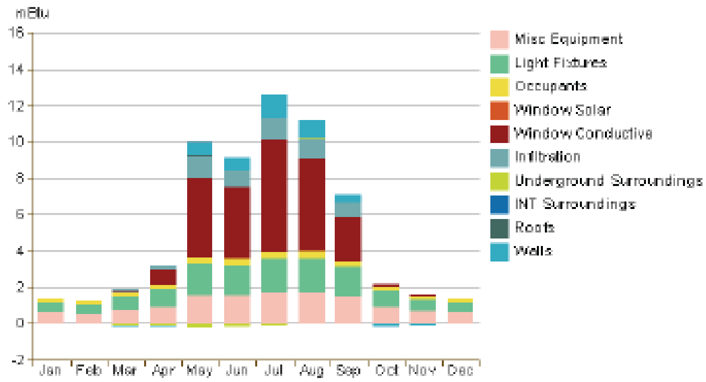
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Monthly Cooling Load



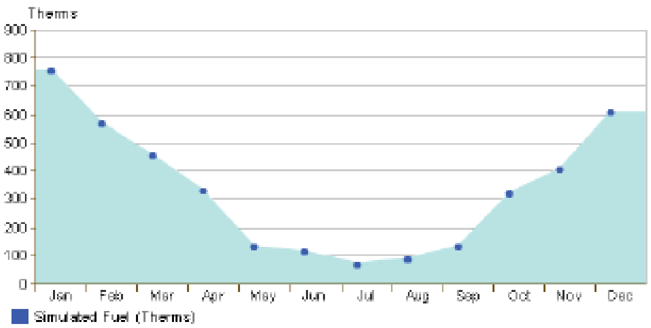
CAPITAL ROW HOUSE
SEER 17
Monthly Cooling Load



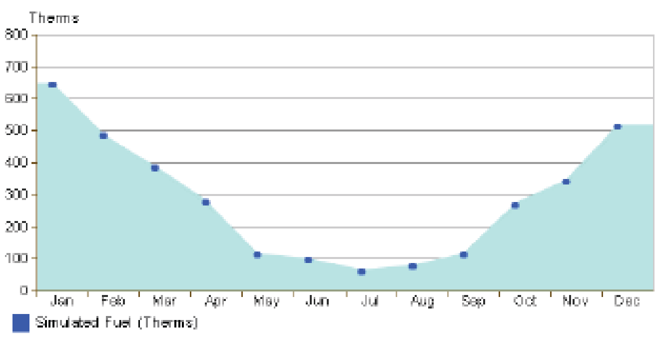
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Monthly Cooling Load



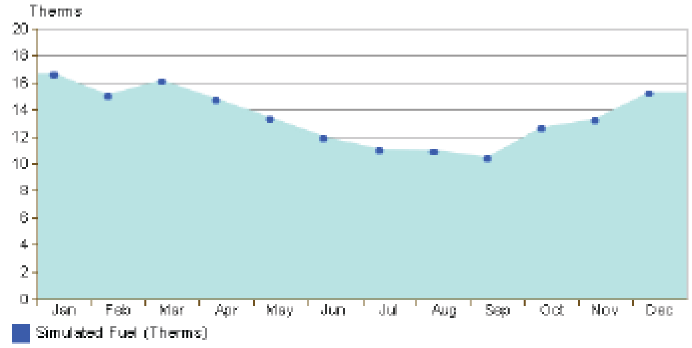
CAPITAL ROW HOUSE
11.3 EER
Monthly Fuel Consumption



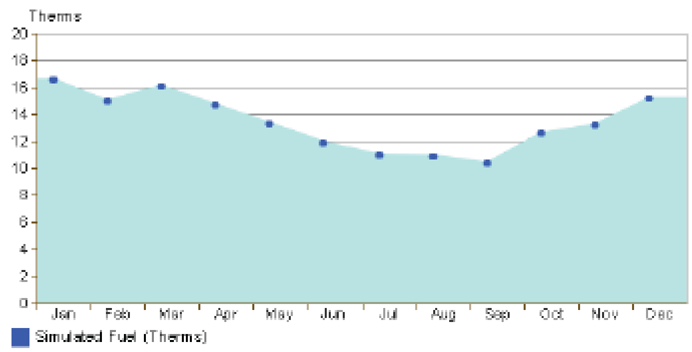
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Monthly Fuel Consumption



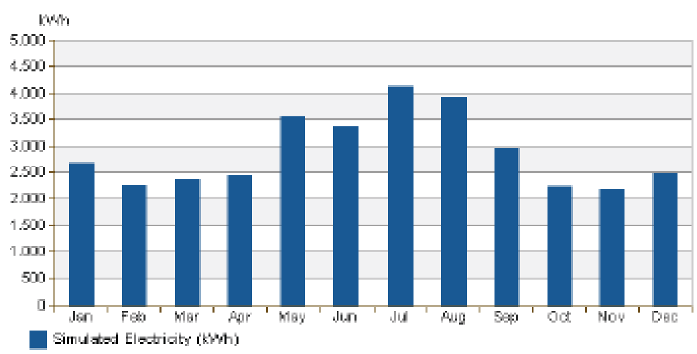
CAPITAL ROW HOUSE
SEER 17
Monthly Fuel Consumption



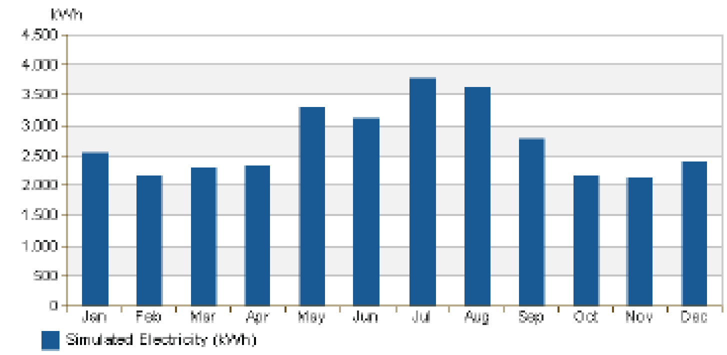
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Monthly Fuel Consumption



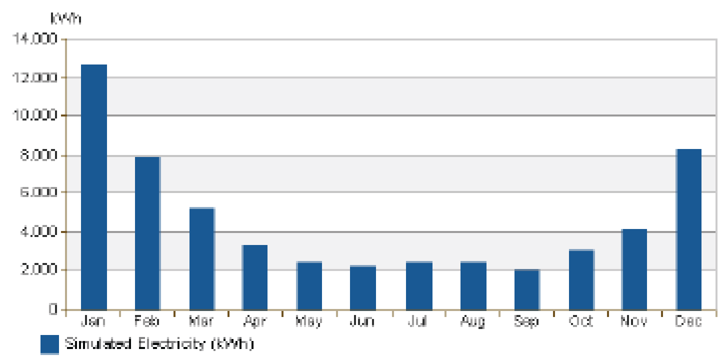
CAPITAL ROW HOUSE
11.3 EER
Monthly Electricity Consumption



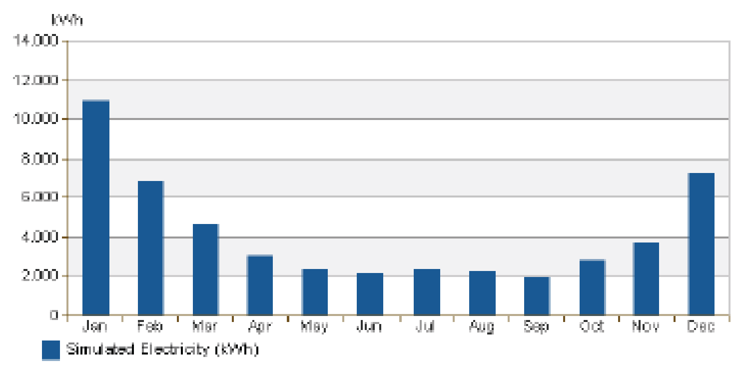
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Monthly Electricity Consumption



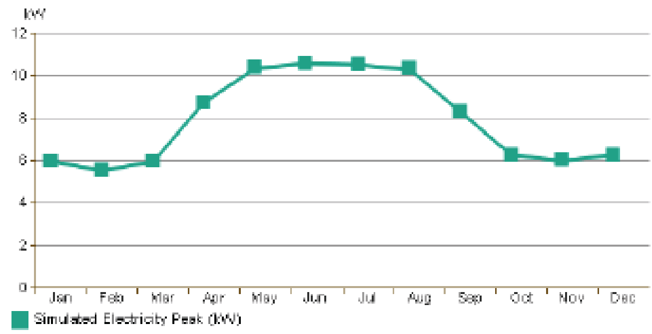
CAPITAL ROW HOUSE
SEER 17
Monthly Electricity Consumption



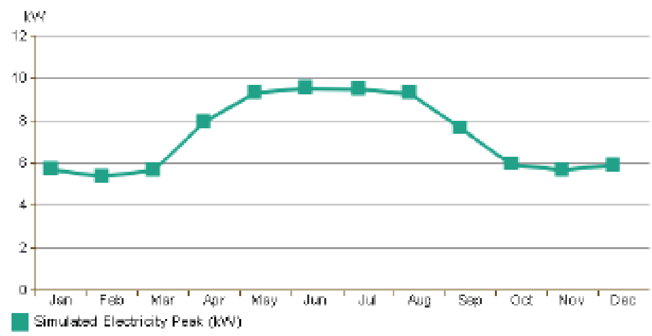
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Monthly Electricity Consumption



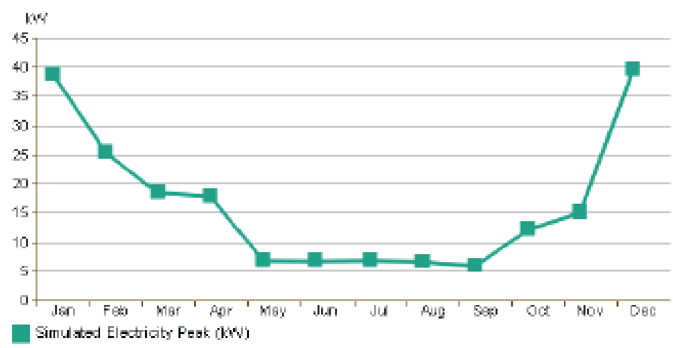
CAPITAL ROW HOUSE
11.3 EER
Monthly Peak Demand



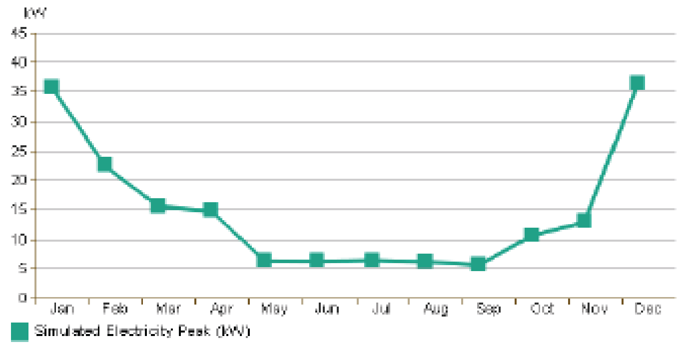
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Monthly Peak Demand



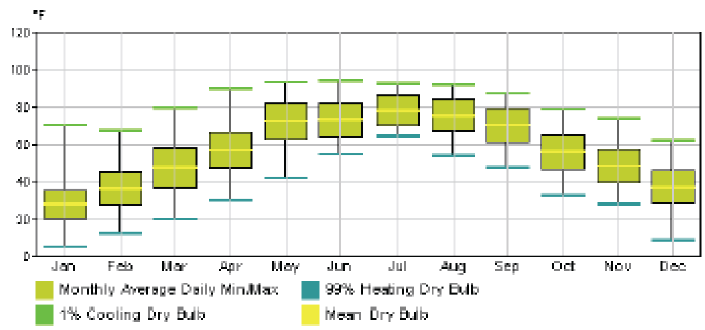
CAPITAL ROW HOUSE
SEER 17
Monthly Peak Demand



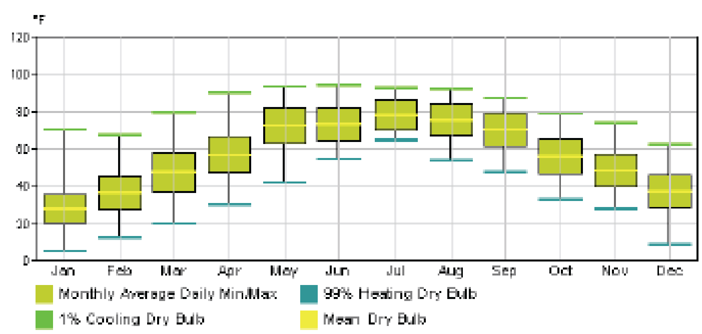
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Monthly Peak Demand



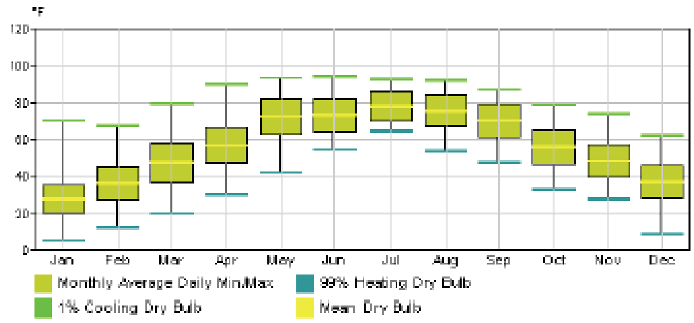
CAPITAL ROW HOUSE
11.3 EER
Monthly Design Data



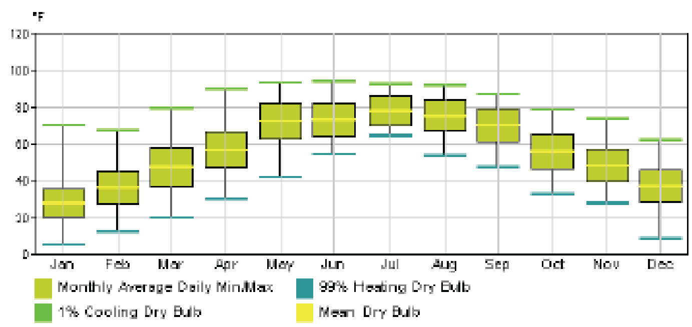
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Monthly Design Data



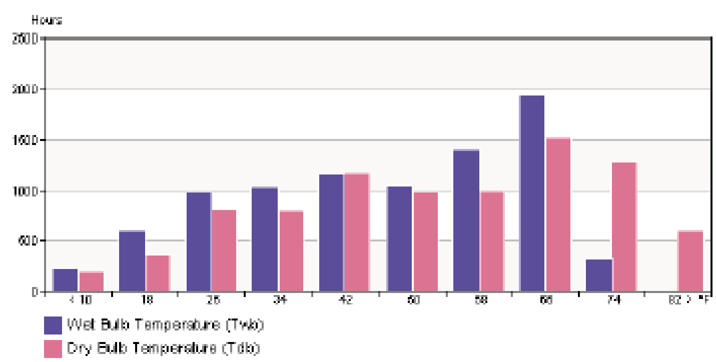
CAPITAL ROW HOUSE
SEER 17
Monthly Design Data



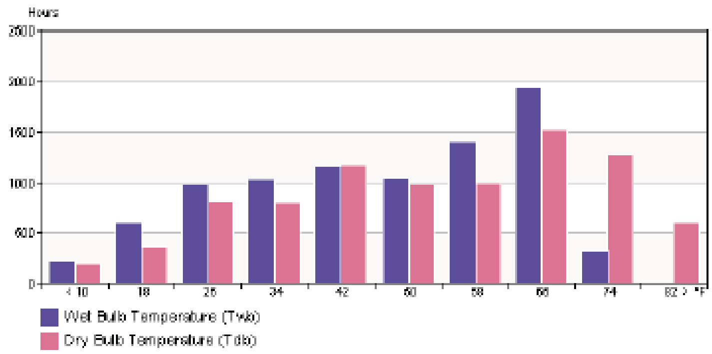
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Monthly Design Data



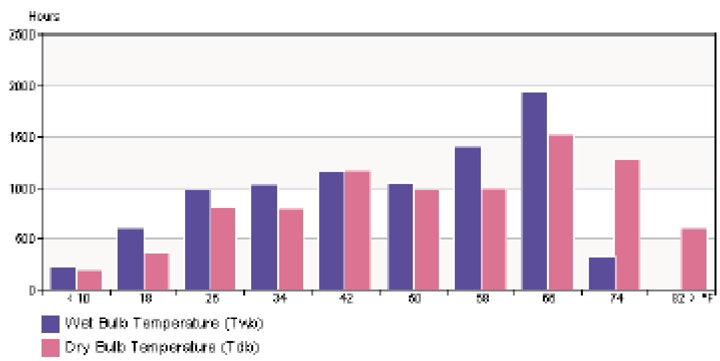
CAPITAL ROW HOUSE
11.3 EER
Annual Temperature Bins



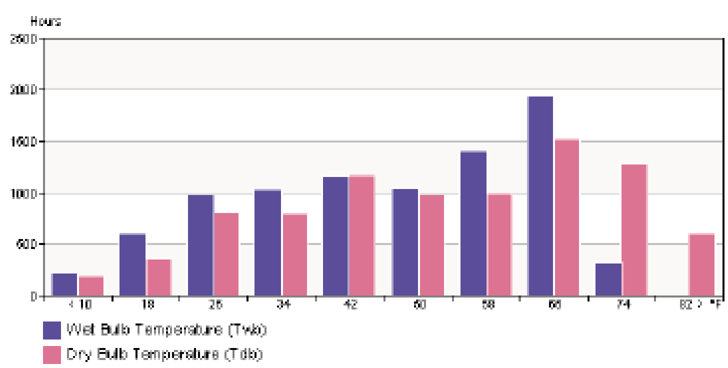
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Annual Temperature Bins



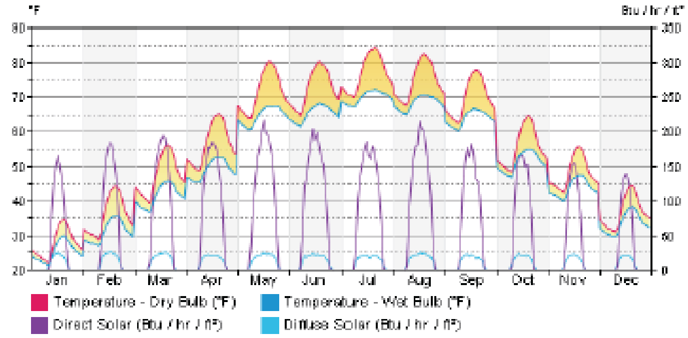
CAPITAL ROW HOUSE
SEER 17
Annual Temperature Bins



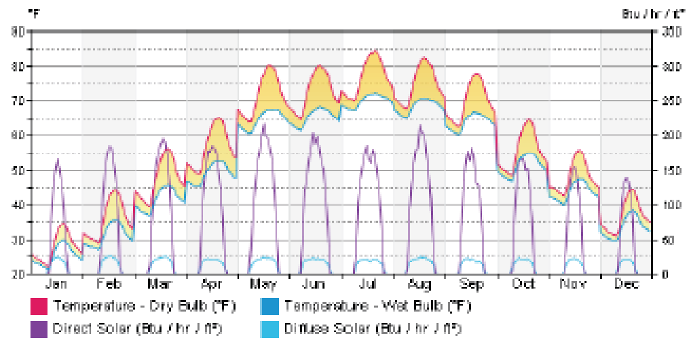
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Annual Temperature Bins



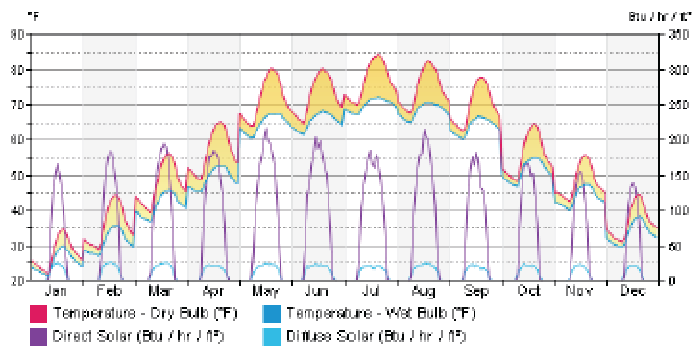
CAPITAL ROW HOUSE
11.3 EER
Diurnal Weather Averages



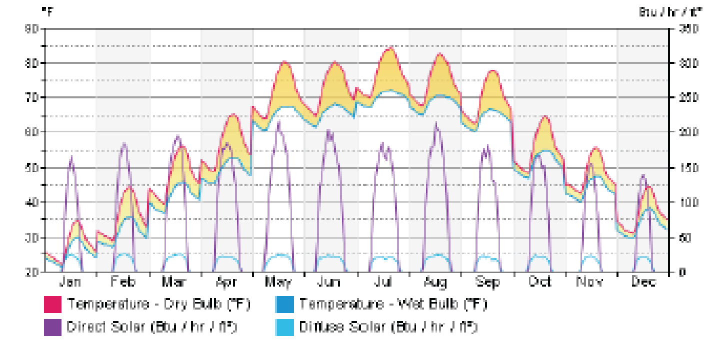
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Diurnal Weather Averages



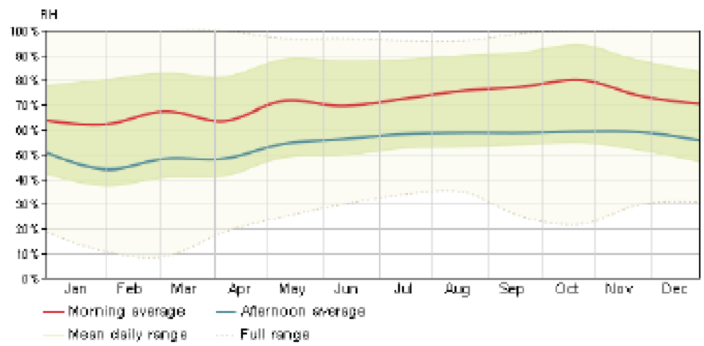
CAPITAL ROW HOUSE
SEER 17
Diurnal Weather Averages



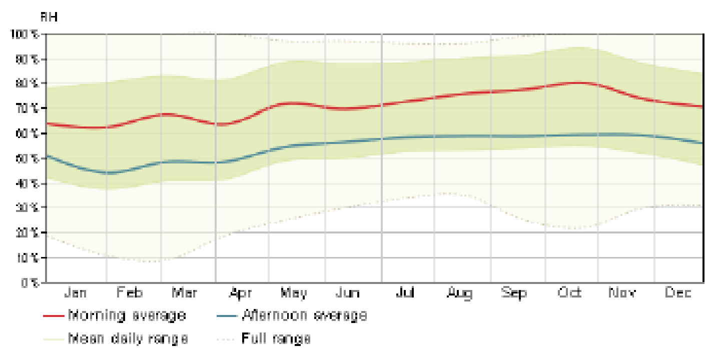
CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Diurnal Weather Averages



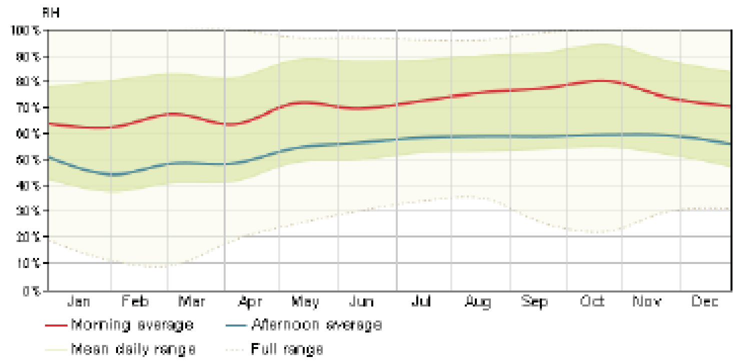
CAPITAL ROW HOUSE
11.3 EER
Humidity



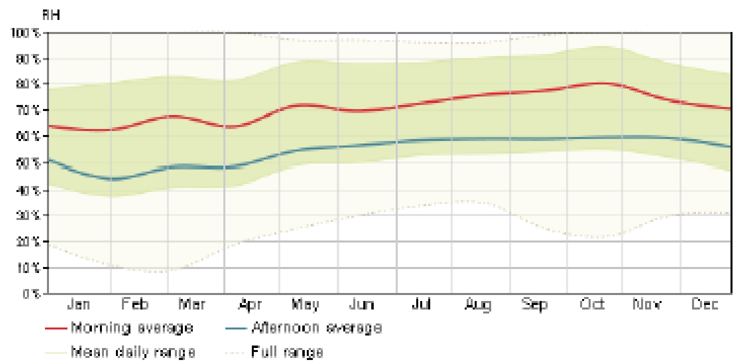
CAPITAL ROW HOUSE
11.3 eer with higher insulation
Humidity



CAPITAL ROW HOUSE
SEER 17
Humidity



CAPITAL ROW HOUSE
SEER 17 Higher Insulation
Humidity



APPLES to APPLES?

EQUIVALENT ENERGY COST COMPARISON OF CONVENTIONAL ENERGY SOURCES w/ GEOTHERMAL HEAT PUMPS

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WATER ENERGY

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Geothermal with Confidence

FIRST -	in **PINK** AREA Enter your Geo Heat Pump's *OPERATING* Htg. and Cooling Efficiencies & Your Elec. Rates		
	Enter the Heat Pump efficiencies and electric unit costs for Summer and Winter		
	Geothermal Heat Pump with a Heating Efficiency* of	**5.3**	**= TOTAL operating system efficiency/COP**
	Geothermal Heat Pumps with a Cooling Efficiency* of	**41**	**= TOTAL operating system efficiency/EER**
	and local delivered electric utility costs of	**$0.1200**	**per kWh (delivered) for Heating (Winter)**
	***Use ISO-13256 Efficiencies (Includes pump correction factors)**	**$0.1900**	**per kWh (delivered) for Cooling (Summer)**

SECOND-	in **GREEN** AREA - Read the EQUIVALENT COST of Purchased Energy			
	COMPARATIVE COST TABLE USING TYPICAL TECHNICAL VALUES - HEATING and COOLING			
	TYPICAL VALUES ARE AS LISTED IN ENGINEERING SECTION BELOW - MAKE CHANGES CAREFULLY			
SUMMARY - If you install a Geothermal Heat Pump, the following conventional fuels would have to cost:				
#2 FUEL OIL MUST cost or LESS than	**$4.00**	**per gallon**	***Heating***	
NATURAL GAS MUST cost or LESS than	**$1.36**	**per CCF/gal.**	***Heating***	**(equivalent $1.32 per Therm)**
PROPANE MUST cost or LESS than	**$2.48**	**per gallon**	***Heating***	
ELECTRICITY MUST cost or LESS than	**$0.120**	**per kWh**	***Heating***	
Air Conditoner Electric Must cost or LESS than	**$0.130**	**per kWh**	***Cooling***	***July 2012 rate - EIA***
Air-Air Heat Pump Electric Must cost or LESS than	**$0.048**	**per kWh**	***Heating***	
Air-Air Heat Pump Electric Must cost or LESS than	**$0.113**	**per kWh**	***Cooling***	***using SEER rating point***

THIRD-	in **PINK** AREA - input your current annual fuel and maintenance cost(s)		
Annual $ with #2 fuel oil		**Computation for Geo vs. my Oil**	**$0**
Annual $ with Nat. Gas	**$4,439**	**Computation for Geo on vs. Nat. Gas**	**$2,195**
Annual $ with Propane		**Computation for Geo on vs. Propane**	**$0**
Annual $ with electric heat/hot water		**Computation for Geo vs. my Elec. Heat**	**$0**
Annual $ with high SEER A/C	**$1,850**	**Computation for Geo vs. my Elec. Cooling**	**$1,266**
Annual system maintenance cost		**Annual Geo maintenance**	**$0**
TOTAL current annual heating/cooling/AC costs	**$6,289**	***Total estimated annual Geo cost***	**$3,461**

Engineering Section - Items below based on typical HVAC performance factors

The below information provides the assumptions and efficiencies used in the computation of the above equivalent fossil and electric HEATING and COOLING COSTS. Also listed for comparison are normalized Heating Costs in Dollars per Million BTU of Delivered Heat.

Note information in the cells below.

= Standard Industry Factors,

= Technical Input by Program User -

#2 FUEL OIL	139,000 Btu/Gallon	88%	=Flame Conversion Efficiency -NORMALLY QUOTED
	$3.05 Per Gallon	85%	=Heat Exchanger & Stack Efficiency
		93%	=Electric Parasitic Effect
		0.70	**= TOTAL Efficiency/COP**
	96,694 =Btu/Gallon Delivered for Heating		
		$31.54	**=Cost Per Million Btu**
NATURAL GAS	103,000 Btu/CCF	90%	=Flame Conversion Efficiency
	$2.75 Per CCF*	88%	=Heat Exchanger & Stack Efficiency
	(*incl winter pipe line charges)	95%	=Electric Parasitic Effect
		0.75	**= TOTAL Efficiency/COP**
	77,497 =Btu/CCF Delivered for Heating		
		$35.49	**=Cost Per Million Btu**
PROPANE	91,600 Btu/Gallon	86%	=Flame Conversion Efficiency
	$3.00 Per Gallon	85%	=Heat Exchanger & Stack Efficiency
		95%	=Electric Parasitic Effect
		0.69	**= TOTAL Efficiency/COP**
	63,612 =Btu/Gallon Delivered for Heating		
		$47.16	**=Cost Per Million Btu**

ELECTRIC	3,413	= Btu/kWh	**0.99**	**= TOTAL Efficiency/COP (Heating)**		
			13	**= TOTAL Efficiency/SEER (Cooling)**		
	$0.1200	= per Kilo Watt (kW) Heating				
	$0.1900	= per Kilo Watt (kW) Cooling				
					$35.16	**=Cost Per Million BTU Heating**
					$14.58	**=Cost Per Million BTU Cooling**
AIR-to-AIR	$0.1200	= per Kilo Watt (kW) Heating				
HEAT PUMP	$0.1900	= per Kilo Watt (kW) Cooling				
			2.1	= COP		
			15	= EER		
					$16.74	**=Cost Per Million Btu for Heating**
					$12.63	**=Cost Per Million Btu for Cooling**
GEOTHERMAL	$0.1200	= per Kilo Watt (kW) Heating				
HEAT PUMP	$0.1900	= per Kilo Watt (kW) Cooling				
		from above	**5.3**	= COP		
			41	= EER		
					$6.63	**=Cost Per Million Btu for Heating**
					$4.62	**=Cost Per Million Btu for Cooling**
Author - Carl D. Orio, AEE certified geoexchange designer #23 updated December 2010						